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JOHN F. KELLY, EDITOR

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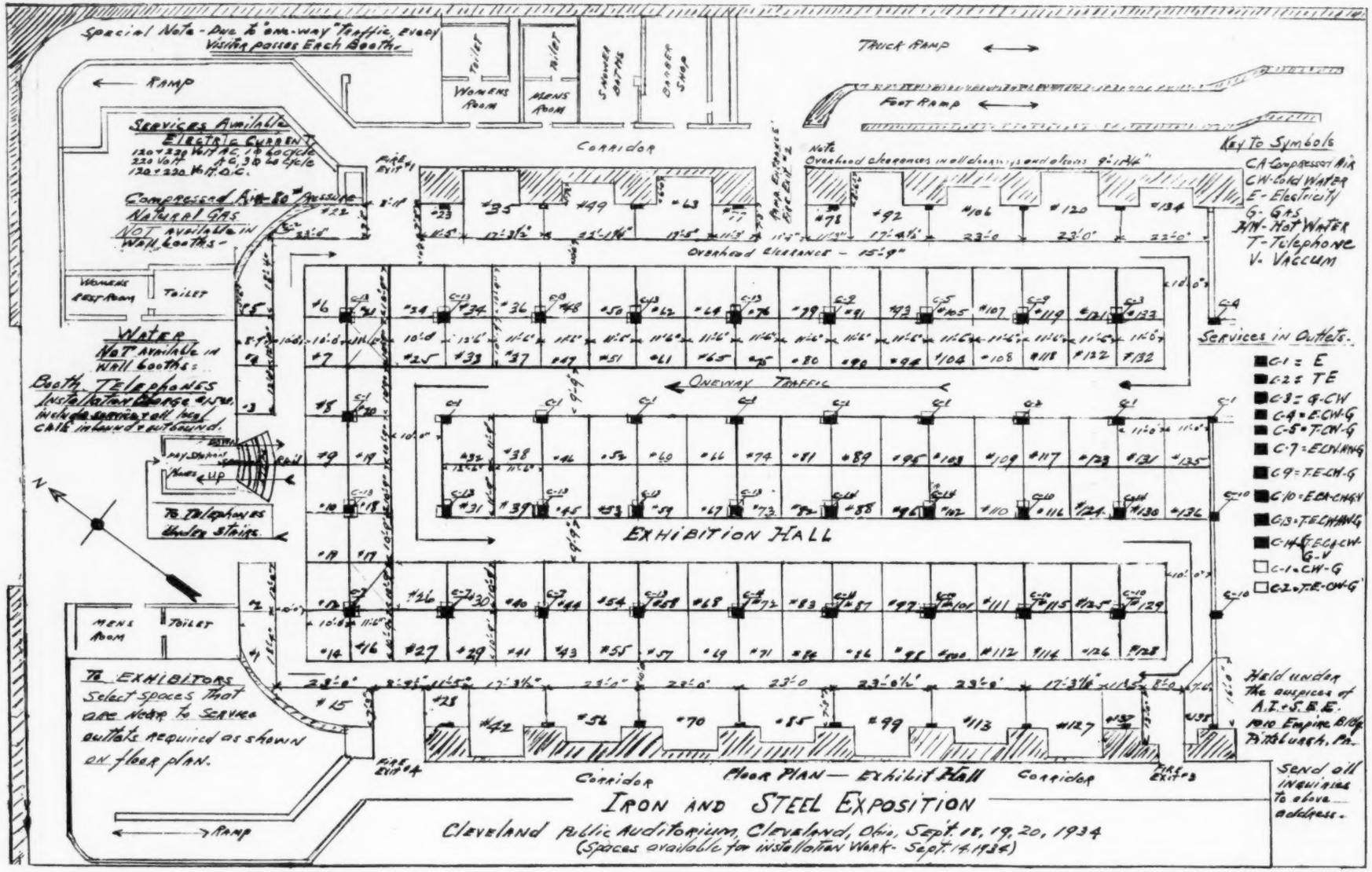
IRON AND STEEL EXPOSITION

CLEVELAND, OHIO, SEPTEMBER 18, 19, 20, 1934



Floor plan of the Iron and Steel Exposition to be held under the auspices of the Electrical, Mechanical, Lubrication, Welding, Combustion and Safety Engineering Divisions of the Association of Iron and Steel Electrical Engineers, Cleveland, Ohio, September 18, 19, 20, 1934. An exposition of the developments in apparatus and equipment to process and produce Iron and Steel.

E D I T O R I A L

Spring Engineering Conference

To explain why 750 engineers and executives from every part of the United States, as well as the British Isles, were in attendance at the annual Spring Engineering Conference, held under the auspices of the Combustion Engineering Division of the Association at Youngstown, Ohio, April 11 and 12, is not, to our way of thinking, such a difficult task.

One of the first reasons we shall enumerate is the comprehensive program of thirteen papers, arranged by the papers committee, which were studies of vital steel mill problems by authors whose experience and prestige is widely recognized in the steel industry. It has been said by some of the leading executives of the steel industry that the program was one of the most instructive ever conducted by any engineering society. Expressions of this nature are indicative of the confidence the steel industry has in the A. I. & S. E. E. to be the medium through which all the latest surveys of engineering progress are disseminated. Also, the advantages to be secured through attending such meetings as these are so apparent and worthwhile that everyone makes a special effort to be present. There is the opportunity to discuss mutual problems with engineers and executives in a manner that is conducive to free expression about plant problems.

In closing, it is desired to be understood that this is not an effort to flaunt success, but merely utilizing an opportunity to remind the membership of the A. I. & S. E. E. that their endeavors are bearing fruit. Also, at this time, the President and Board of Directors of the Association wish to extend their sincerest appreciation to all those who in any way were responsible for the success of this conference.

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Hot Galvanizing In Connection With Sheets

By NELSON E. COOK,
Gen. Supt. of Galvanizing Operations, Wheeling Steel Corp., Wheeling, W. Va.

Presented before the Combustion Engineering Division of the A. I. & S. E. E. at the Spring Engineering Conference, April 12, 1934 at Youngstown, Ohio.

NELSON E. COOK

The age old problem of corrosion has been responsible, in a great measure, for the development and use of protective coatings. For centuries iron and steel have been very important assets in the development and advancement of engineering and building construction. In recent years this material has been used for an increasingly large number of articles until, at the present time, we might well say that iron and steel are our most important base materials for metal work. Iron and Steel have very definite and important properties which account for their success. But they have one very important disadvantage which would make their use much more limited if there were not some way to overcome this disadvantage.

Iron and Steel, when exposed to the moisture of the air, corrode very rapidly. When this moisture in the air contains acids or corrosive salts, the corrosion is greatly hastened. For example, a steel sheet, exposed to the air in the Youngstown District, will corrode much more rapidly than one exposed to an atmosphere in some outlying country district where the air is free from corrosive materials. It is true that, for some purposes, iron or steel will last long enough to accomplish its purpose without applying some outside agency to prolong its life. However, it is becoming increasingly important that we attempt to lengthen the life of many iron and steel products. Therefore, this problem of corrosion of iron and steel has necessitated the development of protective coatings which, in any one of a number of ways, protect the steel base from this wasting action and retain, as nearly as possible, the original properties of the iron or steel which made their use advantageous.

Many methods have been employed to combat the problem of corrosion. Time will permit only a mention of the more important. One method, used industrially to protect tools, machines, and working metal parts from corrosion, is by covering or slushing the steel or iron with oil or grease. Another method is to cover the steel surface with paint. Another method is to form, in one of a number of ways, an oxide on the surface of the metal, which will increase its corrosion resistance. The most important method of protecting iron or steel is by coating it with a protective layer of some other corrosion resistant metal.

Among the most common metals used for this purpose are copper, lead, tin, nickel, cadmium, chromium, zinc, and aluminum. Some of these metals, when applied to an iron or steel base, exert a much greater protective action than others, for very definite reasons. Without going too far into the highly technical reasons, it might be stated that these metals may be definitely arranged in a series according to their reactions to one another, when placed in a favorable medium for reaction. We find that they arrange themselves in this manner.

Copper
Lead
Tin
Nickel
Iron
Cadmium
Chromium
Zinc
Aluminum

All those metals which precede Iron in this series are electronegative to Iron, and all those which follow Iron are electropositive to Iron. Therefore copper, lead, tin and nickel, are the electronegative metals, and cadmium, chromium, zinc and aluminum, are the electropositive metals. In this paper I shall confine my discussion to the electropositive metals, and more especially to zinc. When two metals come into contact with each other, in the presence of an electrolyte, or when they are introduced into conditions which are favorable for chemical or electrochemical action, the one that is electropositive to the other will be preferentially acted upon. This is the meaning of electropositivity. Referring to zinc especially and assuming that it is in contact with iron or steel, in the presence of an electrolyte which, in a particular case, we shall assume, is the moisture of the air, a galvanic or battery action is set up in which zinc, being electropositive to the iron or steel, is preferentially acted upon. In other words, in the case of a zinc coated sheet, when the condition arises that a part of the steel base is exposed, the zinc will be preferentially acted upon and the steel base will not deteriorate until such time as there is not enough

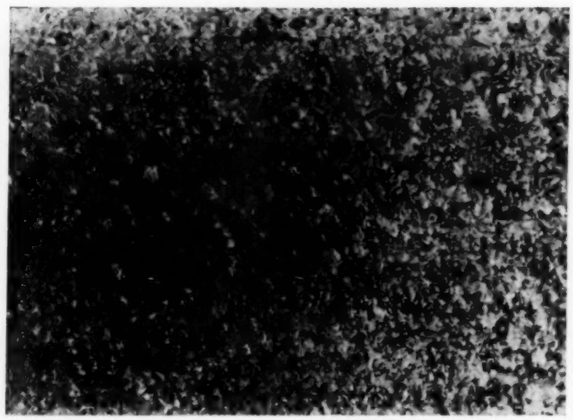
zinc left to cover up this exposed area of steel by electrolytic action.

Therefore, on account of the fact that zinc is electropositive to iron, on account of the fact that zinc coatings may be easily and economically applied, and on account of the fact that zinc is a relatively cheap metal, galvanizing has steadily become more and more important until, at the present time, it is one of our most important protective processes. We do not, however, wish to leave the impression that other metal coatings do not give a protective advantage to iron or steel. Protective coatings function in three ways. First, they may give mechanical corrosion protection to the base metal; secondly, they may give an electrochemical protection to the base metal; and thirdly, they may give both mechanical and electrochemical protection to the base metal. In general the electropositive metals give the maximum corrosion protection, and, in the case of zinc, we get both mechanical and electrochemical protection. Each type of metal coating has its peculiar application which makes it ideal for a particular purpose. For maximum corrosion resistance a zinc coating is ideal, but for other specific purposes zinc, on account of various other reasons which cannot be gone into here, would be unsuitable, and other types of coatings would be used.

Surface picture of a sheet having a fairly good spangle.

The term galvanizing is, in some ways, a misnomer. It was originally applied to this particular art on account of the galvanic protection afforded iron by a zinc coating, which, of course, has nothing to do with the process of coating, itself. We have continued to use this term since the early days of zinc coating.

It is true that zinc coatings are very valuable on account of this galvanic protection. But the fact is that a zinc coating, when properly applied is, in itself, a very resistant coating even before galvanic action takes place. If a sheet of steel is entirely and thoroughly covered with zinc, there will be none of the base metal exposed to the atmosphere, the coating being continuous. Therefore, the atmosphere attacks only the zinc coating, forming insoluble compounds such as zinc oxide and basic zinc carbonate which, being insoluble themselves in ordinary atmosphere, act as a further protective coating. These white oxide coatings are often referred to, very incorrectly, as "White Rust", which term would give us the impression that the article is actually rusting when, as a matter of fact, it is acting exactly as such a coating should act in order to give proper protection to the base metal. Of course these compounds which are insoluble in ordinary atmosphere may eventually be dissolved by an acid atmosphere or may become loose and be mechanically washed away, and, in time, will expose parts of the steel base. Up to this time of exposure of the base metal we have had the advantage of an excellent protective coating. From this time on the added advantage which makes zinc one of our best protective coatings, asserts itself. The exposed iron or steel, by reason of the galvanic action which now takes place, is coated over with zinc oxide or basic zinc carbonate, which protect it from further action. As this oxide or basic carbonate is washed away, again exposing the iron or steel base, galvanic action will continue, successively, until the zinc around this area is used up, in which case the exposed area of the sheet then becomes too large for further action with zinc at a more distant point on the sheet, and corrosion of the base sheet will then start. This action explains why, when galvanized sheets are cut, the exposed steel edge will not rust immediately but will, on



A surface picture of a sheet having a bad spangle appearance.

A cross section view, at 250 magnifications, of a coated sheet, showing the zinc, zinc-iron alloys, and steel base.

account of the galvanic action with zinc, be covered over with zinc products, producing the result which we know under the term,—"bridging of zinc."

Zinc coatings may be applied in a number of ways, each of which has advantages and disadvantages, and each of which, for various reasons, has certain limitations. In order to present to you a rather complete picture of the scope of galvanizing we will touch very briefly on some of these methods. The first is the application of zinc by electricity, called Electro-Galvanizing. This is sometimes referred to as the "cold" or "wet" process to distinguish it from the more common hot galvanizing method. Theoretically this method should be an ideal one but, practically, it is more or less limited to the coating of small articles such as rivets, nails, screws, sockets, etc.

A second method is the metal spraying process, which has its application in the zinc coating of finished, formed articles which, on account of the severe drawing and bending operations put upon them, could not be coated before forming.

A third method is the Sherardizing process, in which the articles to be galvanized are packed in a mixture of zinc dust and sand, and heated for some time, this treatment causing the zinc to diffuse into the iron or steel base.

The most important type of galvanizing is the "Hot" method, in which the article is actually dipped in molten zinc. This method may be accomplished in two ways; first, by coating the articles automatically or semi-automatically, known as machine galvanizing, and secondly, by actually hand dipping the articles in the molten bath. Sheet, pipe, and wire galvanizing fall into the first class, and hardware, ware, and range boiler galvanizing fall into the second class. Of the two methods the machine, or semi-automatic method, accounts for most of the tonnage galvanized. The machine method has its chief application in the zinc coating of steel sheets which are to be used either flat or in such formed articles as conductor pipes, elbows, furnace pipes, tanks, roofings, refrigerators, culverts, and hundreds of other articles. Each of the different methods of galvanizing furnishes enough material for an unlimited discussion. We shall limit this paper to the hot galvanizing of steel sheets by the machine method.

Galvanizing of sheets has been practiced for at least 100 years and no doubt had its beginning in England. The same general methods were used but the product was made for entirely different purposes than the product which we make today. The old galvanizers did not have the variety of sheets and analyses of steel to contend with that we have today. They applied coatings in practically the same way as we do today except that they were, in those days, interested only in maximum corrosion protection, and hence were interested in rather heavy coatings. They did not have such a variety of machines which subjected the galvanized sheets to a severe forming operation, and hence were less interested in the problem of flaking than we are today. During the last twenty-five years there has been a gradual and definite trend toward specialized coatings, there has been a gradual development of machines and operations which form galvanized sheets into a great variety of articles, and hence a great amount of research has been done and is being done to perfect galvanized coatings for specific uses. There has been a gradual trend toward increased efficiency in the coating operation, and to a more perfect product. During this development the galvanizer has had to enlist the knowledge of practically all branches of engineering. He has had to familiarize himself with the manufacture and properties of the various types of sheets which are now used. He has had to familiarize himself with various types of heat treatment, pickling, and cleaning. He has had to coordinate the knowledge of the metallurgist, electrical engineer, mechanical engineer, combustion engineer, and chemical engineer, and to couple that knowledge with his knowledge of metals, fluxes, and treatments, in perfecting the best type of process for the particular kind of coating which he desires to make. He has had to control weights of coating, make different types of coating with different properties and appearance. He has had to make coatings which will withstand severe forming operations without flaking. In short, the whole problem of galvanizing is so complicated that it is small wonder that we refer to it as an art. Very little authentic literature concerning galvanizing is available. Patent literature, however, is replete with different types of galvanizing processes, machinery, and developments. New practices, types of coatings, treatments, etc., are being developed daily, and it is for this reason that galvanizing of sheets is one of our most interesting arts.

At this point in our discussion it would be well to explain some of the general theories in the coating of zinc on steel sheets.

The general mechanics of the coating operation are as follows: A steel sheet is cleaned in any one of a number of standard methods, fluxed, and passed through a molten zinc bath. This bath is at some temperature above the melting point of zinc. The sheet, in passing through this molten zinc, gradually assumes the temperature of the zinc, and the zinc actually alloys to the steel base. If we were to examine a finished, coated, sheet under a microscope, we would find a series of rather well defined layers of varying compositions of iron and zinc. We would see, first, the steel base, then an alloy layer of iron with a small percentage of zinc, then successive layers of varying compositions of iron and zinc, then an alloy layer of zinc with a small percentage of iron, and finally, on the outer surface, a layer of practically pure zinc. These layers are bonded, one to the other, and hence form a product which is completely alloyed from the outside to the inside. In general, alloys of zinc which are high in percentage of iron, are very brittle. Hence, even though we desire this alloying effect, it is often necessary to regulate this alloy formation in order to produce the tightest possible coating.

One of the most misunderstood characteristics of a zinc coated sheet is the "spangled" or crystallized effect of the zinc coating. Chemically pure zinc, when applied to a steel sheet will not, on cooling, show a well defined spangle formation. The general conception is that the spangle comes from the zinc itself. This, however, is not the case. A metal bath for coating is a complicated one and requires the highest amount of skill to mix, in order to produce desired results. Prime Western Spelter is the

grade of metal usually used for galvanizing. This metal contains small percentages of lead, cadmium, iron, and tin, as impurities. The lead, being only slightly miscible with zinc at high temperatures, settles to the bottom of the kettle and affords protection to the bottom of the kettle. Cadmium and tin are two of the metals responsible for the flowery or spangled condition of the finished sheet. Therefore, since we must have small additions of other metals to zinc in order to produce spangle, this explains why, when we use Prime Western Spelter, we naturally get spangling effect. Several other metals may be added to the zinc in small percentages to produce different spangled effects, such as bismuth, aluminum, antimony, and even mercury, each of which produces a different effect, and each of which in different combinations with others, produces a different effect. A skilled galvanizer, then, must have a very complete knowledge of metals and alloys in order to produce a desired effect on the finished sheet. There are other ways in which the galvanizer may regulate the size and appearance of the spangle formation, such as the regulation of amount of pickling, regulation of the heat of the coating bath, regulation of the time in the bath, and by the regulation of the degree and rate of cooling of the sheet after it emerges from the metal bath.

There is one very important contributing factor to the appearance of the finished sheet which is very often set aside as being of minor importance but which, in reality, is just as important as the metal mix. That is, the type and condition of the steel sheet which is used for coating. We now use several types of steel sheets and several different analyses of steel. Each of these steels anneals in a slightly different way. Each of them, then, forms alloys with zinc is a different way, and each of them will form a different spangled effect, all other things being equal. The size and appearance of spangles is partly dependent on the release of the latent heat of the coating metal, and the number of points at which crystallization of the zinc will start. Oftentimes, in order to produce definite spangle effect, artificial points of crystallization are set up.

No doubt most of you have watched galvanized sheets coming through the coating process and have wondered why, with all coating conditions apparently the same, one sheet will have a beautiful spangled appearance, and the next one to it will have very small spangles. This condition may usually be traced to the properties of the steel base, or to the treatment of the base before coating. There are several explanations for differences in spangled appearance caused by the kind and condition of the steel base. In setting forth some of these explanations, it should be remembered that the reasons are very general and are more or less theoretical. Such explanations may be generally applicable to our problems but do not always hold true, especially since there are so many other variables which influence spangling conditions. In general, however, if the base sheet is smooth, the sheet and the coating will conduct heat rapidly and to the same relative degree. In this case, the zinc coating will cool with the formation of large spangles, all other things being equal. Conversely, if the base sheet is rough and porous and contains air pockets or impurities, the heat conductivity of the steel base will be very much less than that of the zinc coating. Hence the coating will cool more rapidly than the base, and, in so doing, a great many points of crystallization will be set up which will then form very small spangles.

Another important factor in the spangling of sheets is the property of the base metal to absorb gas from the pickling operation. In general, if a sheet absorbs gas in pickling excessively then, when it is put through the coating bath, the natural tendency is for the gas to be driven out on account of the heat of the bath. But, the alloy of zinc and iron forms on the surface of the sheet during this process, and, since this alloy has a higher melting point than the zinc itself, it will lay on the surface of the sheet as a slush. The gas, then, in trying to escape from the base sheet, disturbs this layer of alloy and establishes several small points which then successively disturb the other layers of alloys which are formed, and eventually disturb the final layer of coating which is put on as the sheet emerges, and these small disturbances establish several points for crystallization of the zinc coating. Hence a very small spangled appearance will result. This and the other theories which I have given you above may be considered as tendencies of the condition of the steel base to change spangling effect, which tendencies may be eliminated or at least partially eliminated or counteracted by some of our other variables. This discussion of spangling is important only in that it brings before you some of the problems with which a galvanizer is confronted. We are not always interested in good spangling. In fact, several processes for specific uses have been developed to decrease or eliminate spangling. Quite naturally, however, if we wish to change a spangled effect, or to eliminate it altogether, we must first know the factors which contribute to spangle formation.

Each galvanizer has his own peculiar way of approaching a coating problem and obtaining results. You can appreciate that these methods are so complicated that time will not permit a thorough discussion of them. Each galvanizer has different ideas as to equipments and methods, and hence it will be possible to give you a brief description of only one accepted set up for hot coating of steel sheets.

Steel sheets are first properly annealed, and this may be done in any one of a number of ways. This annealing process forms a thin oxide on the surface of the sheet which must be removed before coating. This is accomplished, in average practice, by pickling in heated acid. In this country, commercial sulphuric acid, or vitriol, is used for this purpose, chiefly because of its cheapness. Other acids such as commercial hydrochloric, or muriatic acid, nitric acid, and others, might better be used, but their increased cost does not usually offset the added advantages. There are several other methods for cleaning sheets, such as scratching or blasting, which may be used for this cleaning operation, but they are not, as yet, commercial practice. After the sheets are pickled they must be washed free of acid by some method, usually by washing them in cold water, and then neutrallizing any remaining acid with an alkali. From this point the sheets are taken to the galvanizing pot and, after inspection, are put into a small tank directly behind the galvanizing machine, which usually contains very weak muriatic

acid, but which may contain any one of several other chemicals. The main purpose of this tank is usually to keep the sheets out of contact with the air, thereby assuring that no further oxidation will take place before the sheets are coated. The sheets are then fed into the galvanizing bath through a set of squeezing rolls, which remove most of the moisture from the sheets. A sheet, to be properly galvanized, should be dry and clean when it first touches the metal. Therefore, each sheet, when it comes from the squeezing rolls is first sent through a flux bath, which usually consists chiefly of ammonium chloride, or sal ammoniac. This removes the last traces of moisture and cleans the sheets of oxides, after which it continues on through the galvanizing machine and zinc bath, which is constructed in such a way and in such proportions, that it is possible for the sheet, in its passage through, to assume the temperature of the bath, thereby assuring time for producing the alloy and assuring a good coating. This coating bath consists mainly of zinc. The sheet emerges at the front of the machine through a set of steel rolls. Sal ammoniac or some other substance of like nature is used at the back of each of these rolls. Since the front rolls are only partly submerged in the zinc metal, and since they are continuously turning away from the sheet, each roll after being in contact with the sheet, in its return path, must pass through this layer of sal ammoniac before again continuing its course through the metal. Any oxide or dirt is dissolved in this flux and the roll will again be clean when it comes into contact with the sheet on its next revolution. These front, or exit, rolls are also used for regulating the weight of coating on the sheet.

There is more to galvanizing than simply passing the sheet through a zinc bath, as I have mentioned before. Like every other process, there is only one correct way to galvanize each class of material, and control of the process must be very definite.

Good galvanizing depends, first, on good pickling and uniform cleaning of the sheet to be coated. Pickling must be watched very closely. It is impossible to set forth a standard pickling practice, for the time of pickling, and quality of pickling, will depend on the grade and type of sheet, type of pickling solution used, type of pickling machine, and freshness of the bath. Temperature control in the operation is very important. It should be positive and should preferably be controlled automatically. The rest of the operation depends on the skill and training of the operator, who must study his process. The days of "hit and miss" pickling have now almost completely passed out of existence and we are now doing our pickling in a very scientific way, under the direction of someone familiar with chemical processes. The results have been very worth while.

The galvanizing machine is important and should be so designed as to give a first class product with the least amount of trouble. The building of a machine requires much skill and experience. Being submerged in the metal bath, it is necessary that exactly the right types of steel and other metals be used in its several working parts to get maximum efficiency with a minimum of repairs. Steels ranging from low to high carbon are used in the several working parts of a machine and the development of this part of the galvanizing process has required much research. There are almost as many different types of galvanizing machines as there are manufacturers of this material. Each of them has been designed to obtain definite results, and each manufacturer has as good a reason as the other for the type of machine he is using.

The metal mix is a complicated one and has been explained previously in this paper. The metal bath must be kept at a constant and proper heat, preferably controlled by pyrometers, for at least two reasons. First, to assure proper coating at a temperature which best suits the grade of material that is being processed, and, secondly, to prevent an excessive formation of Dross, a bi-product of the process. Due to the fact that some of the iron from the sheets, kettle, and machine, is dissolved in the zinc bath, a heavy zinc-iron alloy is formed, called Dross, which, on account of its having a higher melting point than zinc itself, settles out as a slush on the bottom of the kettle. This dross must be removed periodically, usually once a week, although the time for removal depends on the amount formed and the point at which such amount interferes with the proper continuance of the coating process. At high heats dross formation occurs very rapidly, and hence it would be impractical to allow the heat of the bath to go above a certain critical point.

The firing of the kettle is important. In this country several fuels are used, including natural gas, coke oven gas, producer gas, powdered coal, coal, coke, and electricity. Some of these fuels have very definite advantages over the others. Some are cleaner and easier to use, some give better heat regulation and more constant temperature, some are less destructive to the galvanizing kettle, and some permit of a more simple furnace design. There is no reason why any one of these fuels cannot be used successfully, and therefore each galvanizer usually uses the fuel which is cheapest and most readily available in his locality. No matter what fuel is used, the furnace design is important for at least two reasons. First, a sheet galvanizing operation, on account of the large tonnages of cold metal which are introduced into the hot bath, presents quite a problem in heating, especially as regards proper heat distribution, and, secondly, proper furnace design is important in order to get maximum life from the coating kettle.

As to the treatment and processing of the galvanized sheet after it emerges from the zinc bath, very little can be discussed in this paper. It is at this stage in the operation that a great number of developments have been made, each of which produces a sheet with certain appearance, properties, and uses. Many of these treatments are old, established processes which have been in use for decades. Some are new and are patented. Others are being developed. For their explanation, patent literature should be consulted. You will appreciate that a galvanizer has an almost unlimited number of variables in his process. The method which I have explained is only one standard succession of steps which might be used. Any one of the steps, or any combination of steps, may be eliminated, and any number of additional steps may be introduced into the process to produce certain results.

In the complete galvanizing process, for sheets,

we use several raw products, and produce several products and bi-products.

The principal raw products used are:

Steel sheets which, as we have seen, may be of any type or analyses of steel.

Commercial Sulphuric Acid, or Vitriol, Commercial Hydrochloric, or Muriatic Acid, Nitric Acid, or any other suitable pickling acid, or combination of acids.

Some form of alkali.

Other materials for blasting, scratching, or treating sheets for coating, provided some other method is substituted for the pickling operation.

Prime Western Spelter, or some other special grade of Zinc.

Tin, Antimony, Cadmium, Bismuth, Mercury, and other metals used for additions to the coating bath.

Sal Ammoniac, Ammonium Chloride, Zinc-Ammonium Chloride, or any other suitable fluxing agent.

Other miscellaneous chemicals.

The principal products and bi-products of the process are:

Finished Coated Sheets.

Zinc Dross Metal.

Spent Flux from the Coating bath.

Oxides.

Spent Acid Liquors, if acid is used for cleaning.

The Zinc Dross metal may be redistilled in retorts, separating the zinc from most of the impurities, and obtaining a very efficient recovery of prime western spelter or a better grade. Spent Flux is valuable for the constituents it contains, and is reworked into several standard materials. Oxides are usually separated in a mechanical way from all metallic constituents, and pulverized into oxides minute enough for paint pigments. Spent Acid Liquors, if dumped, should be neutrallized, but this liquor may be treated and evaporated to recover iron sulphate, or what is commercially known as Copperas.

Of course our most important material in the process is the finished galvanized sheet. In conclusion I would like to discuss the different types of coatings, their uses and limitations.

In designating the weights of zinc coatings we refer to them as having so many ounces of zinc per square foot of surface, which includes both sides of the sheet. For example, when we refer to a 1 ounce coating, we mean that the sheet has approximately 1 ounce of zinc per square foot of the sheet, both sides, or approximately 0.50 ounces of zinc per square foot on each side of the sheet. Zinc coatings, and particularly coatings of the alloys of zinc, are more or less brittle, and, unlike some of our other coating metals, do not withstand a bending or forming operation very satisfactorily, the coating peeling or flaking away from the base sheet. Therefore we must regulate the weights of coating so that the ratio of the thickness of coating to the thickness of the base sheet is in the proper relation for withstanding the particular operation which may be demanded of it. Zinc coatings on sheets are now produced by the hot process in a wide range of weights, from as low as 0.50 ounces per square foot up to approximately 3.00 ounces per square foot. Uniformity of this coating is an important thing. Most manufacturers now make zinc coatings with a maximum variation of approximately 20% between the heaviest and lightest coated spots on a sheet. The uniformity of the coating is dependent, of course, on other variables aside from the variables which the galvanizer can control in his process. For example, non-uniformity in steel analysis, with subsequent non-uniformity in pickling, will produce non-uniformity in coating. Also, uniformity of coating is determined, to a great extent, by the uniformity of gauge of the sheet. In general, since the galvanizing machine is set for one standard, uniform, coat, any thick or thin spots in the sheet will of necessity take a different weight of coating than the standard average, the thin parts of the sheet taking a heavier than average coating, and the thick spots taking a lighter than average coating. In spite of all these variables, much work has been done and most manufacturers are now producing fairly uniformly coated galvanized sheets.

As to the uses and limitations of different kinds of zinc coatings, we may make the following very general, random, observations.

1. When sheets are to be used either flat or with very light forming, such as corrugating, and where maximum resistance to corrosion is the important factor, the coating may be very heavy, bright in appearance, and coated with nearly pure zinc.
2. When galvanized sheets are to be used for severe forming operations, a light weight coating is usually used, the weight of coating depending on the maximum amount which may be applied with safety, in order to prevent flaking or peeling in the operation. Usually these coatings are made with an alloy of zinc, the coatings are not very bright, and appearance is not so attractive.
3. When the trade demands a heavy, rigidly specified coating weight, with required tightness of coating sufficient to withstand a severe operation, this type of sheet should not be considered as commercial, for it must be coated with special processing.
4. When a galvanized sheet is to be subsequently painted or lacquered, the coating should be made in such a way that we will get maximum adherence of the paint or lacquer to the zinc coating. There are several ways to make this type of sheet but the important thing to remember in this type of coating is that we should be interested not only in producing a sheet with maximum paint adherence properties, but we should also aim to make a coating with as much corrosion resistance as possible.
5. In general, the purer the zinc coating, the greater the resistance to corrosion.
6. In general, the heavier the zinc coating, the longer is the life of the sheet. We must remember that this is not strictly true, and we are not to assume, for example, that a 2.50 ounce coated sheet will have 2½ times the corrosion resistance of a 1.00 ounce coated sheet, unless they are compared under the same conditions. The life of a coated sheet depends on the locality in which it is used, the purpose for which it is used, and on the

treatment which the sheet receives before use. For example, a 1.00 ounce coated sheet, used as a roof in Vermont, may last just as long as a 2.50 ounce coated sheet, used on a roof in the Youngstown District.

7. As a general rule, bright spangled appearance does not go hand in hand with extra tight coat properties and we cannot obtain both things on the same sheet.
8. Estimation of lifes of zinc coated sheets and relative resistance to corrosion of different weights of coatings, are dependent on so many variables that no artificial method of accelerated corrosion testing has yet been devised which is satisfactory. Actual long period weathering tests in different localities have been conducted by several Engineering Societies, which have now proceeded far enough to indicate general trends, from which conclusions may later be drawn as to the values of different coatings and weights of coating. These published results are most interesting.

This paper has, necessarily, been an abstract one, but I trust that it has given you some insight into the many problems of galvanizing which make this art such an interesting and progressive one. In past years the galvanizing industry has progressed very rapidly. The sheet galvanizing industry is not a small one, for in 1928 this country produced over 1,500,000 tons of galvanized sheets, which was an increase in production over 1924, of approximately 50%. You can easily figure that this 1,500,00 tons was equivalent to several millions of sheets. In the last few years, due to prevailing business conditions, this output has been considerably reduced. But it is reasonable to assume that, when conditions are again favorable, we will have at least the same proportionate increase in the use of this product that we have had in years past. It is not too much to assume that galvanized sheets will find several new applications in addition to those we now know. These new applications will no doubt demand new requirements but we are convinced that the galvanizer will find new ways to cope with these problems. And so we are entirely justified in believing that hot galvanized sheets will continue to hold a most important place in the general scheme of steel production.

New Fuels and Their Application

By MARTIN J. CONWAY
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Paper presented before the Philadelphia District Section of the A. I. & S. E. E., April 7, 1934.

With only a short time at my disposal, I want to deal with two new fuels or rather new uses for two fuels well known to all of you. Namely, liquid petroleum gas and heavy fuel oil. Liquified petroleum gas is obtained by separating the light fractions from natural gasoline and also from refinery operations during the distillation of crude oil. It consists of propane (C_3H_8) and butane (C_4H_{10}). Because each hydrocarbon compound has a different chemical formation and consequently different physical characteristics, these two products, propane and butane, can be separated in fractionating towers which operate on the principle of distillation under pressure. These gases concentrated into liquid form are easily stored in pressure tanks of A. S. M. E. Standard and both of these liquid gases are available by tank wagon and tank car delivery, are non-corrosive, and have an exceptionally low sulphur content of about 2 to 3 grains per 100 cubic feet.

Both propane and butane can be readily converted into gas, butane through a suitable vaporizer and propane by simple reduction of pressure, and, due to their high concentration of thermal value, can be transported in small pipe lines to the point of consumption, the gases containing 3200 B.t.u. per cubic foot of undiluted gas. The advantages in the distribution of petroleum gases are—

1. For a new pipe line system the investment is lower than for a system to handle low B.t.u. gases

MARTIN J. CONWAY

such as artificial or coke oven gas, due to the much smaller pipes, valves, and fittings required.

2. For existing system, distributing low B.t.u. gas, the thermal carrying capacity is automatically increased, providing a more uniform burner pressure and ability to add additional outlets without increasing the size of the pipe lines or add new pipe lines.

Propane has a vapor pressure of 120 pounds at 70° F., a boiling point of –44° F., and a B.t.u. value of 92,850 per gallon, while butane has a vapor pressure of 33 pounds at 70° F., a boiling point of 26° F., and a B.t.u. value of 102,400 per gallon.

The fuel is suitable for use wherever manufactured gas can be used from baking bread to large annealing operations and has been in use for this latter purpose during the past few years by such companies as the A. O. Smith Corp., Chrysler Corp., and Sun Shipbuilding Co. It has also been used as a metal cutting substitute for acetylene.

Its advantage is due to the fact that with a small, simple, compact plant, any industry can generate its own gas economically in competition to the present manufactured gas rates, this together with low sulphur content makes it a desirable fuel for heat treating operations and the like, with a small adjustment to burners where manufactured gas has been used.

In addition, in the liquid form it has every desirable characteristic of gasoline, yet possesses additional advantages obtainable from no other existing motor fuel. Propane has an octane rating of 125 which makes feasible the use of compression ratios in the neighborhood of 10 to 1. Because the normal state of the fuel is a gas it has instant starting characteristics, forms little or no carbon, and eliminates crankcase dilution. Also there is a decrease in specific fuel consumption.

Some sixteen million gallons per day being available at the present time and very little more than one days available supply was consumed in the year 1932 although its use had increased 85 times in ten years, there being 200,000 gallons used in 1922 and 17,000,000 consumed in 1932, so it is hardly probable that consumption will make an appreciable inroad on the supply for many years.

One of the interesting developments in the generation of power is the advent of the low pressure semi-diesel engine using heavy oil as fuel.

The flexibility of this unit will appeal to steel plant engineers. Briefly, some of the operating and performance data are as follows:

Heavy fuel oil is fed to the engine at approximately 150° F. and pressures varying between 4,000 and 10,000 pounds depending on the size of the engine and load characteristics. This heavy fuel oil is thoroughly cleansed of moisture and grit by passing through a centrifuge; normally not more than 20 pounds of B. S. is extracted from a 500 gallon batch of 12 to 16 Bé oil. Units have been designed from, less than 100 horse power to 7,000 horse power, the larger units developing one I.H.P. per hour on .32 pounds of oil. In addition, the larger units can be equipped with waste heat boilers of the water tube type, evaporating one pound of steam from and at 212° F. for each developed horse power hour at the engine. These units hold their efficiency across an operating range of from 25 to 100 per cent of their rating.

Engines of 3,000 horse power and larger have been in use on vessels directly coupled to the propellor shaft for several years, and some land installations have been made with equal performance success.

The interesting feature of this type of installation is the fact that a cheap fuel oil can be used which otherwise could not be applied to internal combustion engines thereby eliminating the steam plant and its standby expense during variable load periods, and at the same time combining flexibility with efficiency.

Design and Application of Gearmotors

By R. S. MARTHENS
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Presented before the Philadelphia District Section of the A. I. & S. E. E., January 6, 1934.

For years machine designers have been attempting to find better means for the mechanical transmission of power combined with speed reduction. Many attempts have been made to find the ideal solution to this problem, which would require having

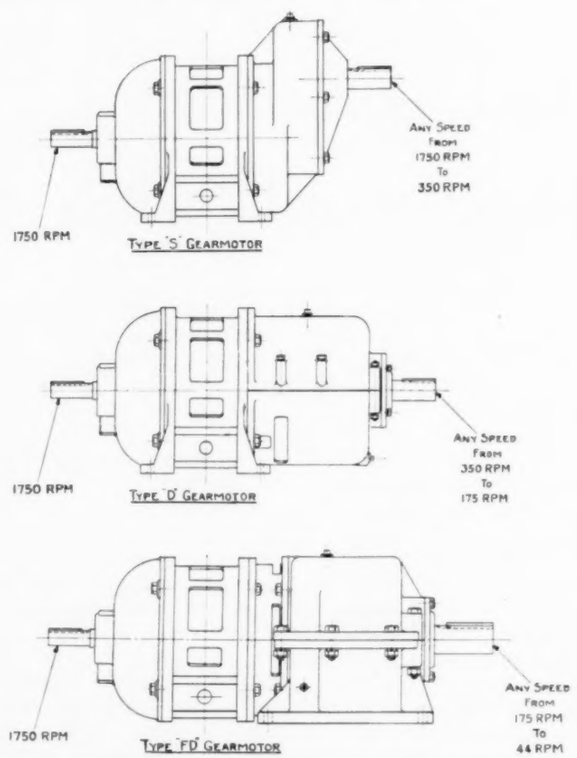
1750 RPM
TYPE 'S' GEARMOTOR
ANY SPEED FROM 1750 RPM TO 350 RPM
1750 RPM
TYPE 'D' GEARMOTOR
ANY SPEED FROM 350 RPM TO 175 RPM
1750 RPM
TYPE 'FD' GEARMOTOR
ANY SPEED FROM 175 RPM TO 44 RPM

FIG. 1—Illustrating the three type gear cases conforming to N. E. M. A. standard frames.

a very compact unit combined with high efficiency, low cost, neat appearance, few wearing parts, long life, and properly enclosed to meet safety requirements. Various types of drives, such as belt drives (both flat belts and V belts), chain drives, rope drives, open gearing, etc., have been developed, but none of them have met all of the necessary requirements.

The gearmotor is more nearly this ideal solution

than is any other type of drive on the market at the present time.

The first gearmotors, of the same general design used at the present time, were built about 1923-25. This development was handled by one of the large motor manufacturers as a possible means of increas-

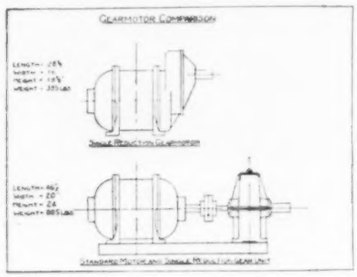

FIG. 2 — Illustrating the savings in space and weight when a single reduction gearmotor was substituted for a separately coupled motor and speed reducer.

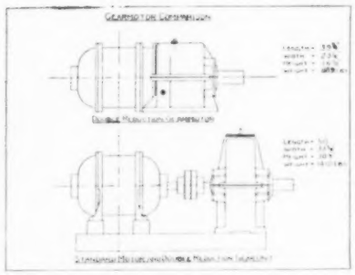

FIG. 3—This application resulted in a saving of 23% in length, 31% in width, 46% in height and 37% in weight.

ing motor sales. No real progress, however, was made until gear manufacturers, a few years ago, realized that the gearmotor was the "coming unit" for power transmission at speeds lower than popular motor speeds and actively began the present development.

Today, a large number of both gear and motor manufacturers are actively marketing gearmotors. A recent issue of "Electrical Manufacturing" carries a list of gear manufacturers and motor manufacturers now marketing these units and this list contains the names of thirty-two companies interested in the popular sizes of 2 H.P. and above.

It is the purpose of this paper to very briefly describe the types of units now being manufactured both from the design and application viewpoints. The illustrations used will be confined to parallel shaft type units as manufactured by the Westinghouse Company.

The practical purpose for which a speed reducer is purchased is to deliver a desired horsepower at a desired speed. A speed reducer is usually associated with a motor, and a combination of motor and speed reducer in one piece of apparatus is obviously the most desirable type of equipment. The particular motor speed and gear ratio chosen by the manufacturer to produce the desired output speed are relatively unimportant.

The principal advantages of the gearmotor over other forms of speed reduction are:

1. Unit may be designed as one piece of apparatus.
2. Lower first cost, including installation cost.
3. Less maintenance.
4. More compact.

When a set of motor parts and gear parts are built as one combined unit, the design can be so arranged that they will both have the same load carrying capacity. Thus if general purpose motor parts are used, the gear parts should also be general purpose, and if hoist motor parts are used, hoist gearing parts should be used.

A comparison of costs for the gearmotor as compared to a separate speed reducer, separate motor, coupling and bed-plate, indicates that approximately 10% to 15% can usually be saved in first cost. This applies to the popular field of from 3 H.P. to 50 H.P. and for output speeds as low as 10 R.P.M.

A comparison of costs for the gearmotor as compared to a set of pulleys and a belt indicates that approximately 10% to 15% can usually be saved.

Installation costs of the gearmotor are also lower than for other types of drives, since a major portion of the checking and aligning is done at the factory and not in the field. Separate motors and speed reducers may be received completely assembled on a base but require a much more elaborate foundation. The installation cost of a gearmotor is approximately the same as for a motor alone.

Because of the fact that there are fewer parts and no exposed parts, the maintenance of gearmotors is less than for other types of drives. Aside from supplying the proper amount and grade of oil, as recommended by the manufacturer, during the original installation, it is necessary only to change the oil in the gearing parts twice a year during service. The motor parts require the usual maintenance.

A comparison of the space required and weight of gearmotors and separately coupled speed reducers and motors indicates savings approximately as follows:

Length	—	15 to 40%
Width	—	15 to 30%
Height	—	15 to 40%
Weight	—	40 to 60%

These savings will be illustrated by line drawings later. This is probably one of the most important factors which influences purchasers to select gearmotors in preference to other drives.

There are three types of gearing which are popular among gearmotor manufacturers:

1. Simple gear train.
2. Planetary gear system.
3. Worm gear set.

Most gearmotor manufacturers of the first two types have chosen single helical gears because of their smoothness of action and high efficiency. Since all gearmotors employ anti-friction bearings, this type of gearing is most suitable.

Worm gear sets are used where right angle drives are required and the lower efficiency is not objectionable.

Several types of gear cases are in common usage:

1. Solid gear case supported from the motor frame.
2. Split gear case supported from the motor frame.
3. Solid gear case with motor overhung.
4. Split gear case with motor overhung.
5. Solid casting with gear case and motor frame integral.

Most manufacturers agree that for reduction ratios greater than 10:1 the supporting feet should be on the gear case with the motor parts overhung. In no case should there be feet on both the gear case and motor frame castings.

When selecting gearmotors for a particular application there are certain features which should be considered entirely aside from the question of first cost.

1. The gearmotor should be adequately supported. The torque to be withstood by the supporting structure is the torque developed by the motor parts multiplied by the gear ratio.

2. The gearmotor parts should be so designed that the connection to the driven equipment may be made by direct connection or through chain, belt, or other gearing. The overhung load capacity of the output shaft of the gearmotor is usually specified by the manufacturer.

3. The maintenance department will desire a unit that may be easily dismantled and reassembled. This applies particularly to the motor parts, but it should be possible to easily inspect the gearing parts also. Where space is at a premium, the gearmotor with the horizontally split gear case is preferred.

4. It is desirable to have the gearmotor arranged so that changes in ratio of speed reduction can easily be made in the field. Quite frequently this change is made either to speed up or down or move the unit to another location. One manufacturer uses a "preferred series" of ratios which gives a definite percentage change in the ratios carried in stock. This gives a "preferred series" of machine speeds in line with plan of the A.S.A.

The gearing designers and the motor designers have laid down certain fundamental principles which

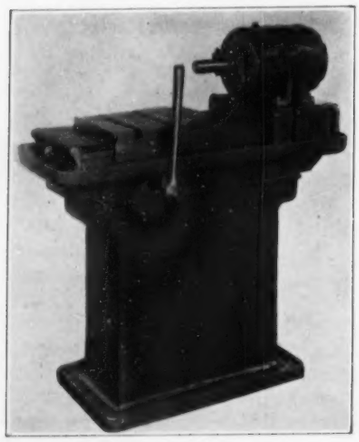

FIG. 4—This shows the application of a double reduction gearmotor to a Bearizing Machine.

have been incorporated into the design of our gearmotors.

These fundamental principles, briefly, are:

1. That the gearmotor shall be developed for general purpose applications and must be capable of delivering the full torque of the motor, and also must have sufficient capacity in the mechanical parts to take any kind of overhung load on the output shaft such as pulleys, chain sprockets, or overhung pinions.

2. That the type of gearing used should be that type which has proved so successful over a number of years in the separately built speed reducers.

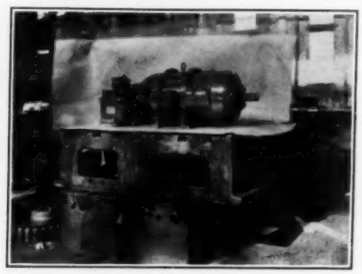

FIG. 5—In this application attention is called to the small pinion mounted on the output shaft and the brake parts on the motor shaft extension.

3. That tests should be made to determine whether the supporting feet for the unit should be on the motor frame or on the gear case.

4. That an adequate oil seal must be incorporated between the gearing parts and the motor parts to

FIG. 6—Shows the application of a single reduction gearmotor to a ventilating fan.

prevent the oil from the gear case getting into the motor.

5. That a series of reduction ratios should be

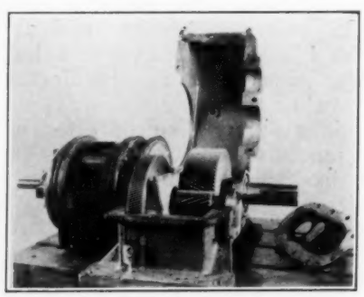

FIG. 7—Illustrates an exposed view of a unit.

available which would enable the manufacturer to stock a limited number of parts and yet meet within close limits any desired output speed.

With these fundamental principles always in mind, we have developed for each of the standard N.E.M.A. frames three gear cases as indicated in Fig. 1. The type "S" gearmotor has in the gearing parts a maximum ratio of 5:1 which in conjunction with a 1750 R.P.M. motor will permit of speeds down to 350 R.P.M.

The type "D" gearmotor, in which the gear case is approximately the same diameter as the motor

FIG. 8—This gearmotor, with a ratio of 40:1, is connected to a conveyor by means of a chain.

frame, has a maximum reduction of 10:1 which with a 1750 R.P.M. motor would permit of output speeds down to 175 R.P.M.

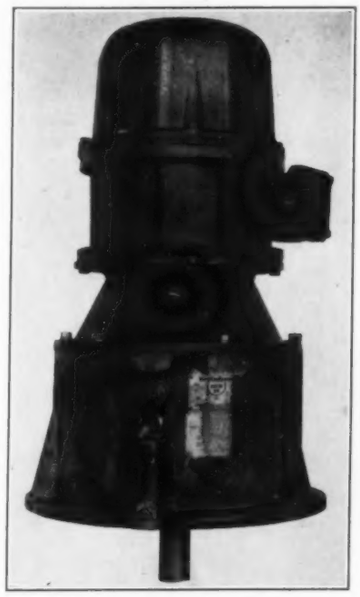

FIG. 9—In this application the output shaft is in line with the motor shaft.

The type "FD" gearmotor is a double reduction unit with a maximum ratio of 40:1 and when used

FIG. 10—Shows the application of a single reduction gearmotor in a modern brewery.

in conjunction with a 1750 R.P.M. motor permits of output speeds down to 44 R.P.M.

Fig. 2 illustrates the savings in space and weight when a single reduction gearmotor was substituted for a separately coupled motor and speed reducer. For this rating of 15 H.P. at 350 R.P.M., the saving in length was 38%, width 20%, height 18%, and weight 55%.

Fig. 3 illustrates the savings in space and weight when a double reduction gearmotor was substitued for a separately coupled motor and speed reducer. For this rating of 15 H. P. at 44 R.P.M., the saving in length was 23%, width 31%, height 46%, and weight 37%.

Fig. 4 illustrates the application of a double reduction gearmotor to a "Bearizing Machine." The gearmotor replaced the complete headstock previously used. A special tool mounted on the output shaft produces a surface which is smoother than grinding and limits of .0002" have been held on finished refrigerator parts.

Fig. 5 illustrates the application of of a double reduction gearmotor to a crane. Attention is called to the small pinion mounted on the output shaft and the brake parts on the motor shaft extension. For this type of application the gearmotor should be doweled in position and adequately supported.

Fig. 6 illustrates the application of a single reduction gearmotor belted to a ventilating fan. Note special inclosure on motor frame.

Fig. 7 illustrates the exposed view of a unit. Attention is called to the use of single helical gearing which has proved so successful in speed reducer practice and has been adopted by practically all manufacturers of parallel shaft type gearmotors.

Fig. 8 illustrates the application of a double reduction gearmotor with ratio of 40:1 connected to a conveyor by means of a chain.

Fig. 9 illustrates the construction of a vertical double reduction gearmotor. The maximum reduction for this unit is 30:1. The output shaft is in line with the motor shaft.

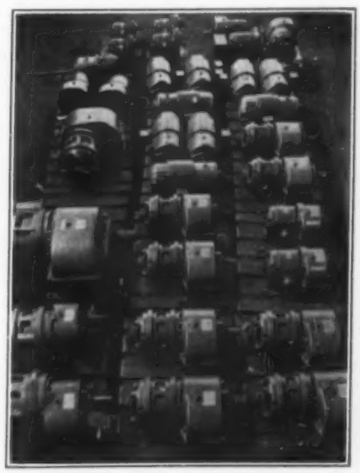

FIG. 11—A number of single reduction, double reduction and variable speed gearmotors of standard and special construction ready for shipment.

Fig. 10 illustrates the application of a single reduction gearmotor in a modern brewery. Attention is called to the splash-proof covers employed.

Fig. 11 shows a number of single reduction, double reduction, and variable speed gearmotors of standard and special construction ready for shipment. There appears to be no limit to the application of gearmotors, either from the question of size or of special features desired.

Discussion

Discussion Presented by

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J. H. Flagg, Watson-Flagg Machine Company, Paterson, N. J.

L. F. Coffin: Mr. Marthen's paper was most interesting, and it seems to me that the manufacturers of gear motors should circularize not only the electrical departments but the mechanical departments as well, because it would appear that the application of gear motors is certainly going to spread on new installations and in many cases, on existing installations, will displace the use of conventional open spur gear drives at least.

There are two questions I would like to ask the speaker. When you receive an order for a gear motor, specifying possibly 7 to 1 ratio, do you make it a practice to furnish it with gears so that the customer, after applying it, may change the gear ratio either way, up or down? In other words, is it your standard rule never to fill up the gear case with the gears, in filling an order?

The other question I would like to ask is, in the case of a stall—possibly on a table roller line in a rolling mill for instance—what is the weak point in the unit? Will the motor stall, or will it blow out, or will the gears fail?

A. J. Standing: I came here primarily to learn and not to tell you anything. I want to compliment Mr. Marthens on the very splendid way in which he handled the presentation of his paper tonight; I think it was a good job and we all profited by the method in which he handled it.

There were a few questions that I had in mind prior to coming here and I have noted a couple more since hearing the speaker. The first one is rather difficult to answer and that is the service life of gearmotor units. I know they have come out in the last two or three years and it would be interesting, but rather embarrassing, I presume, to find out the number of failures and the causes of failure, the thought being, that there are perhaps weaknesses which are included in the first design of these motors which will only show up after we get them into plant service, and those weaknesses will undoubtedly be cured, as they have been in all other apparatus supplied to steel mills, and the sooner we go through that process of sore throat and measles, the better, and I would like to know what has happened in that respect.

Another question is lubrication. I noticed the statement that you lubricated twice a year. That is rather a doubtful answer; it would depend, I should think, to a large extent on the speed and the nature of the service, the conditions under which it operated, the changes in temperature, and it might be a rather important point to develop some standardization of lubricant for different types of service or, at least, advise the customer not to stick completely to the twice-a-year program for lubrication.

Now on the question of maintenance and what is going to be the limiting factor from a load standpoint, what is going to fail, whether your gears are going to strip or tear, or is your motor going to stall, or will adequate motor protection, which we are accustomed to now, be sufficient protection for gear units in whatever ranges of speed you are operating. We have the new Nema line of motors, which we have become accustomed to now and, as we get into the gearmotors, that is going to upset all standardization and I realize that if there are thirty-two manufacturers in the gearmotor game now, certainly we will have to go all through the N. E. M. A. procedure again before we get any standardization in gearmotors.

One question, before I touch on applications, that has appealed to most of us is foot strength and the application of feet. As many of us as have looked at the matter, have had as many different opinions perhaps as to the proper location of the feet, and I am interested in the statement that the feet would not be applied both to the motor and to the gear. I believe that was his statement?

R. S. Marthens: I would say they should not be, that's right.

A. J. Standing: Should not be? Well, in that case you probably will have torques exerted which will require a stronger foot mounting, stronger foot design, than would otherwise be necessary on the motor alone or on the gear alone.

There are a number of applications which have cropped up in various plants. We have a number under consideration at the present time. One very interesting one is the application to soaking pit covers, that is, the old style soaking pit covers, which are now hydraulically operated, at a considerable expense of maintenance for the hydraulic source of power. We experimented, first, by taking the worm-driven unit from one of our open hearth doors

—there being enough surplus open hearth furnaces now that you can easily do that, and applied this to the soaking pit with sprocket and chain drive, and arrived at quite a workable drive except that the worm unit was too high and in danger of being damaged by carrying ingots over the top of them. Then we figured that a compact reducer unit, in the same application, would keep it very close to the top of the pit cover and give you all the advantages, and probably more, than we had with the worm-driven unit. And if that works out successfully, it will lead to the elimination of considerable hydraulic expense.

Another point is the machine tool builders' slant. We buy a lot of machine tools from time to time, and if any of you are not familiar with them electrically it would be of interest to come in contact with them. The machine tools are all designed, as you know, for sixty cycle speeds and every time we in the 25-cycle end of the line have to go back at them, it requires some adjustment—changes of mounting, different sized motor, different gear reductions and so on, and now it might be feasible to have a gearmotor line developed to cover just the 25-60 cycle differences in speeds.

For instance, the other day we had some machine tool propositions, we sent out our motor data sheets and the reply came back stating—"realizing that you people have 25-cycle, we will accommodate our machine run at 1150 or 850 RPM." Nice concession they made to 25 cycle.

Now one other point—the question of lubrication of bearings of your geared units, are they lubricated from the same source as the lubricant in your case? Is that always the source of lubrication?

Going back to my original statement, the change in temperature would considerably affect the viscosity of the lubricant and might produce some trouble with bearings.

I want to congratulate the Philadelphia Section on this turn-out of all the new and some of the old.

G. H. Schaeffer: So far as the subject goes, up to the present time my knowledge of gearmotors was obtained from the magazines, but after listening to this, what I would consider a very able paper, I don't feel that I am a stranger to the gearmotor any more. I was particularly interested and impressed with the remark that Mr. Marthens made to the effect that the gears were designed to meet the type of motor. I mean by that the general purpose motor would have gears designed for the strength of a general purpose motor, while a mill type motor would naturally have stronger gears. I would like to be corrected by the speaker if I am wrong in that supposition. Now, along the line of Mr. Standing's remark about the base strength, I would conclude from the speaker's remarks that the strength of the base feet would also be increased to meet the special type of motor under consideration. I feel as though each gearmotor installation should be treated as a separate installation, a separate study made of it so that we would be sure, in connection with the overhang, the force and so forth, that the requirements would be met, and I imagine that in a lot of the cases there will be an outboard bearing necessary.

That's about all I have. I certainly do appreciate the paper.

R. F. Gale: In listening to the paper tonight, the application appears to be almost unlimited. The speaker did not talk much about series motors used as gearmotors. Gearmotors would appear to be just about ideal for a carbottom drive where floor space is not always available. To overcome gear fracture or failures of another character, stalling resistance could be placed in the electric supply circuit, limiting the torque well below the breaking point of any part of the apparatus in question.

I am in full accord with the speaker, Mr. Standing and Mr. Schaeffer that the gearmotor should be designed stronger than the motor.

F. O. Schnure: If I may revert to football parlance, my position on gearmotors has been that of "holdback", for two reasons, first is lubrication and the other, well, we'll come to that latter.

The lubrication of gears is one thing and lubrication of motor windings is another, which is what I've been afraid of, and I think practically everybody else has been in the same boat. The gear manufacturers insist, in fact they are sure of it, that they have cured this fault, but I am rather skeptical. In steel plants we have felt safest when we could put our motor far enough away from the gearbox to install, if necessary, some sort of barrier to prevent the grease or oil if there was leakage, from getting into the motor, but like all other things, I suppose there will be an answer found to this and that our gear boxes will be made grease and oil tight.

On the question of spares—the second point or reason for my holdback position—has been the fact that if one ordinarily carries a spare motor for every ten or two for every twenty or something in that order, when you start to install gearmotors you immediately must carry a spare for that gearmotor in its particular ratio, and when you commence to multiply the ratios, carrying a spare for each different ratio, I can see where a wholesale application of gearmotors will very easily multiply the investment in spares.

Now, those, so far as I can see, are the two principal objections. On the other hand, it presents a very nice way to apply an A. C. motor to a drive which might ordinarily require a D. C. motor because of the speeds that might be required. And in our plant we have weakened a little bit in the last six months and have applied several, maybe a dozen, or even more gearmotors. So far as I know they are all operating very nicely.

When we come to the application of those gearmotors—our engineering department largely influenced us in having the feet placed under the gearbox itself, no matter whether it was fifteen horsepower or five. Another point of preference was that it should be a straight line drive, that is, the power output from the gearbox, the shaft, should be in line with the motor shaft. One reason for coming to that conclusion was that we thought possibly that would make more for interchangeability, from one job to another.

I believe that the use of gearmotors is going to grow with us because I believe they are an improvement in the art of applying electric power to all kinds of drives.

J. Hertrick: I am glad to say a few words about gearmotors or motorreducers as we term them. We manufacture a drive where the motor and gears are

mounted in one common casing. This eliminates the question of whether the supporting feet should be on the reducer or on the motor.

Our casing is divided by a wall with the gears on one side, and the motor parts on the other side. By taking off the front end bell, the rotor with the pinion can be directly taken out; the prewound stator, too, can easily be pulled out and replaced by a spare if necessary. Taking the rear end bell off gives free access to the gears.

To seal the gear case from the motor we applied first a patented seal, but it did not work out entirely satisfactorily for this special application. We then used friction oil seals, the same as were shown during the lecture. However, these too, gave us some trouble because on large high speed motors they created heat and occasionally burned out. We then designed a new rotating seal which has an outside diameter equal to the outside diameter of the motor shaft bearing. The bearing and seal are put on the shaft with a permanent press fit. A combination of special grooves on the seal and in the housing in connection with an oil return, provides a strong sealing effect. This seal worked out to our complete satisfaction.

For any emergency—say if the reducer would be filled up too high with oil, we have on the motor side, a baffle which prevents any oil from reaching the motor winding and returns it to the bottom of the housing, where it runs out through a hole provided for this purpose. On the low speed shaft we use standard friction oil seals.

For explosion proof motors, up to now, we bolt the reducer on the motor, or a round frame motor on the reducer. Where the reducer is too small to bolt the motor on it and yet when the reducer is bolted on the motor, the overall length of the unit is large in relation to the distance between the motor feet; then the result will be an elastic mounting which is liable to produce excessive vibrations. In a case like that we find it advisable to put an additional foot on the reducer. The feet on the reducer and motor should be machined after assembly so as to be in the same plane.

When talking about the size of a motoreducer, we must understand that for standard units the size of the gear housing is automatically settled by the size of the motor.

In the past we selected a required reducer for a given horsepower, input speed and ratio and applied the correct service factor, but for motoreducers, the gear housing is designed for the maximum ratio. It is our practice to design the gear end strong enough so it will take with the largest ratio, the full load of the motor for the lifetime generally taken for reducers and to withstand at all times, the maximum torque the motor will develop.

Now—if a manufacturer wants a standard unit especially strong he selects a unit with a ratio smaller than the maximum given in the catalog. The horsepower capacity of the gears is then increased in about the same proportion as the ratio is reduced. If we furnish a motoreducer which has a ratio of one-half the maximum, the gears are good for twice the horsepower the motor develops.

I think that is about all I have to say concerning the particular points discussed this evening.

W. E. Miller: Mr. Schnure has covered two of the points I had in mind. In my opinion the feet should be placed under the gear box with the motor overhung, rather than under the motor with the gear box overhung.

I think also that it would be better if the drive shaft were in line with the armature shaft, but I can appreciate the difficulties that would be met in building such a unit.

It was not clear to me what type bearings were used in connection with the units which employed helical gears, whether proper provisions for taking care of the end thrust were embodied in the bearings. Helical gears, in my opinion, are alright provided the end thrust encountered with their use is properly taken care of.

Another question I have in mind is the efficacy of the oil seal between the motor and the gear reducer under severe temperature conditions. For instance, should a gear motor be applied to a table where there was a possibility of the table being left for a time loaded with hot steel? The gear motor might, in this case, become extremely hot, and the oil seal should be effective in preventing the flow of oil to the motor windings under these conditions.

These are the only points I happen to think of and am interested in.

W. G. Hummel: The points I had in mind have been pretty well covered so far as our reducers are concerned, by Mr. Hertrick.

I might add, to the questions brought out by Mr. Miller, that we also feel it is advisable to have the slow speed shaft in line with the motor, because if there is an overhung load on the slow speed shaft it is closer to the base of the reducer than with the eccentric type of drive and, of course, with our construction, we also feel that it is far superior for supporting the overhung load, upon the reducer than on the motor. This applies to the feet, as well as the size of the holding down bolts on the motor. So far as the slinger was concerned, for keeping the oil out of the motor, we found that due to the high speed of the rotor shaft, the friction type of seal was not satisfactory because of the excessive heat generated, and for that reason we have gone to a slinger of the centrifugal type and have found that to work out very satisfactorily.

H. K. Hardcastle: In the pictures on the screen I noticed that the motors apparently were all A.C. motors. I was just wondering if these gear reducers were also available for direct current motors.

P. A. McTerney: In answer to the gentleman's question, when first brought out, these gearmotors were supplied with general purpose induction motors, but the demand has so increased that we have had to build them for practically every type of motor, that is—polyhase, direct current, single phase and many of the mechanical variations.

L. C. Lucas: I would like to ask whether there is any difficulty encountered with the heat of the motor being transferred through the shaft and frame and contributing to the heat in the reduction gear, thereby helping to break down the oil in the gear casing. Secondly, it has been my experience, with reduction gears, that it is much more economical to use a gear reduction with the nameplate rating about fifty per cent higher than the motor rating because the motor (any standard motor of a given rating) will stand more punishment than a gear

reduction of equal rating and as a consequence it is advisable to standardize on a fifty per cent higher rating on reduction gears than the motor rating. I am wondering whether that has been the experience of others.

J. H. Flagg: I enjoyed Mr. Marthens' talk very much indeed; it has been very interesting to get this slant on his experiences in this gearmotor field, which has been an equally interesting subject for us during this same period.

Our experience has influenced us to follow a somewhat different principle in applying gearmotors, it is of the General Electric gearmotor that I speak, for we recognize that various types of applications involve radically different load reactions, which affect the gear element in an entirely different manner than they do the motor.

We customarily think of loads in terms of horsepower but it is important to remember that this is an overall measure of work done involving three components of force, time, and distance and a proper analysis of the load problem requires an investigation of these individual components, particularly force, or what is more commonly called torque.

In a motor we are reasonably familiar with this force component in the characteristics of full load torque, starting torque, and max. torque values and most of us know how these torque values will vary with the speed or operating characteristics for motors of identical horsepower rating.

The flywheel effect of the motor rotor represents an additional source of peak torque energy values that is frequently overlooked but which has a very definite influence on this force component that we are investigating.

As an illustration, consider the problem of selecting the horsepower required to operate a punch press or a reciprocating compressor. The momentary force required at the peak of the stroke is relatively enormous but because the duration is brief, the theoretical horsepower or work done is a relatively low value. To connect a power source directly to this load would require a force component equal to the instantaneous peak demand and to obtain this without storing up reserve energy in a flywheel would require a so-called horsepower rating many times the actual work done.

In-direct connecting a motor to this type of load the so-called horsepower rating of the motor will depend on the max. torque characteristics and the WR^2 stored energy value or flywheel effect. Careful flywheel design and high slip and peak torque rating of the motor will reduce the apparent horsepower rating of the motor required but it would be folly to conclude that the so-called horsepower rating or physical proportions of a gear set connected between the flywheel and the load could be similarly reduced, as the gearing must withstand the maximum instantaneous peak force.

Another parallel case, expressed a little differently is the design of cam shaft gearing for a gasoline engine. Here these gears are transmitting apparently the simple load of the cam shaft and you would expect this gear load to increase with the number of cylinders, or number and stiffness of the valves. However, as a matter of fact, some of the cheaper grades of engines, particularly four cylinder types, actually require heavier timing gears than larger powered engines of 6, 8 or 12 cylinders with a much heavier cam shaft or apparent gear load. This is of course due to the smoothing out of power impulses, so that the overall load is more evenly applied, and the momentary torque or force at any given instant, is closer to the average torque value for the entire cycle, than would be the case under conditions of variable velocity, with accompanying acceleration and deceleration of the load.

It must be borne in mind that gear transmission involves a positively interlocked mesh, where the force is applied through direct physical contact and it is the maximum intensity of the force at any given instant and not the average of the cycle, that determines the working stress on our materials.

On the other hand, the torque reaction in a motor occurs through electrical lines of force rather than any mechanical interlock, and fluctuations in load tend to be smoothed out by the flywheel effect of the rotor and the resulting deceleration or slip, causes a thermal reaction or heating rather than any mechanical stress. The heating varies directly with the intensity of the force and radiation permits it to cool off between peaks so consequently in this case, the average load value is the determing factor in our basis of rating.

A gearmotor therefore involves these two elements of radically different physical reaction characteristics in combination—and recognizing these distinctions, we divide our gearmotors into three general classifications which we find effectively covers the essentially individual load characteristics of various types of applications.

Our so-called general purpose type is intended for applications involving steady loads where the peak torque value of the duty cycle rarely exceeds the average full load torque value of the motor. A characteristic application for this class of unit is on conveyors where the max. peak torques usually occur in starting and such fluctuations of load as might be expected would rarely exceed the normal rating of the motor.

Our so-called special purpose type is intended for pulsating or fluctuating loads where recurring peak torque values of the duty cycle may amount to 150% of the average full load torque. The gear elements are of the same general design, but of correspondingly heavier physical proportions in consequence of the higher intensity of stress from this class of load. Consequently these units operate at lower than average unit working stress under normal loads so they are also recommended for steady load applications that may be required to operate continuously at full load for twenty-four hours a day.

There is still a third group involving peak torques of even higher values, where the gear characteristics should be especially selected to meet the individual conditions. Such applications would include crane and hoist duty or similar service subject to heavy shock or severe overloads. Also in this group would come rapid full load reversing or plugging service, where the motor is operating at its peak torque rating practically continuously. It is important to note that the kinetic energy effect of a sudden reversal of load, sets up a shock reaction and intensity of stress at least double that of the same force continuously applied.

The danger of over-stressed conditions due to peak torque values above the average for a given horsepower rating, lies not in the probability of actual gear failure but in the premature and excessive wear. The positively interlocked gear teeth under such conditions, are subject to an excessive deflection which creates an out of pitch condition that sets up impact or increment loads that are considerably in excess of the actual transmitted load, and the gouging of the tooth flanks, in combination with the surface fatigue at the area of contact, tend to destroy the involute profile. The resultant damage to the tooth surface during such a period of abnormal stress becomes progressively worse, and is ultimately reflected in a reduced span of life.

We believe that gears should be rated and sold on a torque basis, but in the absence of commercial agreement on this score, and in consequence of the generally accepted practice of expressing such capacities in terms of horsepower, you will find that we definitely define our capacity ratings according to class of service.

R. S. Marthens: I am sure that is quite a list of questions. It appears to me that some of the same questions are occurring in the minds of quite a few of you. I will try to go right down the list as I have jotted them down and if I miss anything, I wish you would call it to my attention.

First question brought out was the fact that we should circularize the operating and maintenance departments and not only the purchasing department and the users. I agree with you there. I happen to be from the engineering department, and some of the salesmen who are responsible for our circularizing of industry are present, and I am sure they won't take offense when I say that as I go around I find there are a few places where they don't know about gearmotors yet. All I can say is that most of the organizations among the gearmotor manufacturers have representatives in the large cities and quite a few of the smaller ones, and this question is new and it has taken some time because of the depression, to get the proper advertising and I am sure they will all be more than pleased to send you loads and loads of literature on gearmotors.

Next question—can ratio be changed? I think most manufacturers are building gear cases which will take care of a large number of ratios within a given case. We spoke tonight of three types—one gear case that had a maximum reduction of five to one; another of ten to one and still another of forty to one. Of course you can get anything less than the maximum in any one of those cases; if you want one to one in the forty to one case, it is yours for the asking.

Another question—what will stall or break? All I can say is that this is a very much discussed question of ratings and I am very glad to have it come into the picture, for this reason: at the beginning of gearmotor development, my experience has been pretty largely with the motor game, and I visualized that if we would do some of the same standardization work in gears that the motor manufacturers had done over a period of years that we would be far ahead in the end, and so we sat down and took from our motor catalog all the ratings that appear on a given N.E.M.A. frame. Take, for instance, a 254-frame, you will find there 220-volt ratings, 440-volt ratings, 550-volt ratings and you will find 25 cycles, 50 cycles, 60 cycles; you will find 2 phase, 3 phase, open type, you will find fan cooled, totally enclosed, explosion resisting, all kinds of motor ratings; and if the gear manufacturer would sit down and take the maximum rating that appears in that N.E.M.A. frame and then design the gear parts to take that torque under any type of load, I am sure that you will find that we will all be better off in the end and that is what our company has attempted to do.

Mr. Standing brought out the question of service life, weakness. All I can say in this connection, without going into it too much in detail and trying to prove my point—which I would be glad to do but it probably is too lengthy for this particular discussion—is that we have in our organization both motor designers and gear designers. I think both of us, that is, both the motor and gear designers, have applied motors and gears into practically every type of installation that is known to gearing or to motors, and it is only by a close tie in between those two groups of designers that the users of gear motors are going to get this thing of having the same capacity in your gears that you have in the motor. I can't say too much about that, because it is one of the fundamental principles that we have incorporated in gearmotors and I think it is fundamentally correct and, as long as we build gearmotors, I am convinced of the fact that we are going to put gears in conjunction with motor parts when we combine them in one unit so that the gear parts will carry any load in any type of application that the motor parts will carry.

The next question brought out was as to the time for lubrication, whether it ought to be twice a year, or monthly, or how we should have it. I believe that for general purpose applications, for the big majority of applications, the lubrication nameplate that the manufacturer places on the unit will be entirely satisfactory. If you, in ordering your gearmotor, have a special application, all I can say is, tell the manufacturer about it and I am sure that with the experience that most of us gear manufacturers have in all types of temperatures and all types of application, that we will be able to recommend the type of lubrication and the particular grade of oil that will be best suited for that gearmotor, and I am sure that if you have the proper confidence in us as gear manufacturers, if you believe our story, that you will tell us about your application when you order the gearmotor, let us do the work of picking the proper lubrication for you and the proper recommendation as to the amount of maintenance that will be required.

Mr. Standing also brought up the question of what will stall or break. All I can say is that in the two thousand applications we have made we have had some tough rackets to contend with, and although in some cases we have broken motor parts and burned up motors, I have yet to see a case where we have stripped any gear teeth.

Next question was in the application of the feet, whether it should be on the gear case or on the motor, and the strength of the gear case. Reference was made to some speed reducer practices that had governed the picking of speed reducers in the past.

I have made a very careful survey of the parts, insofar as the dimensioning of the parts was concerned over our present line of gearmotors and our previous line of speed reducers, and I am telling you very frankly that the gearmotors have more liberal dimensions than the previously used speed reducers. I don't know of any case where we have even come up to—or come down to—the dimensions that we used on speed reducers in working out the designs for our gearmotors. They are all much more liberally rated than were the old speed reducers.

Then the question came up about 25 cycles, and I am glad that did come up because in preparing this paper, I had intended to say something about the fact that the steel mills are calling for 25 cycles. I would like to say in that connection that since we have made the gearmotor parts good for any rating that appears in N.E.M.A. frames, so far as N.E.M.A. frames go, if you want 25-cycle parts you can get them, just as well as you can get the 60-cycle parts. There are 25-cycle windings developed for the N.E.M.A. frames and you can put 25-cycle parts into our gearmotors just as easily, and have the same factors of safety, that you have if you put in 60-cycle parts, and I don't know of any reason why the steel mills should not use gearmotors and use them with 25-cycle parts, if they care to, or use them with 60-cycle parts.

The question came up in connection with the lubrication of bearings, whether it was the same source as is used in the gear case, changes in temperature, etc. I believe, in the two thousand applications that we have made—we have hit some, of course, that have been put on the hot spot and one case comes to my mind where recently we made an application that went down to the very southern part of Florida and they had a room operating temperature, in a phosphate drying machine, of something like 140 degrees, and we have these gearmotors installed down there operating very successfully and I am sure that if you tell us that the application you have is unusual, tell us what it is and the things that are out of the ordinary in connection with its operation, we will be able to, and be glad, to work out the problem for you.

Another point Mr. Standing mentioned was in connection with the standardization program. I think he is a little bit worried about all the standardizations that have been made and whether that is going to be somewhat curtailed, now that gearmotors are becoming so popular in all industries. I am sure that the gearmotor manufacturers will find it highly desirable to do the same thing that the motor manufacturers did, and I will have to leave it with you that where we use the feet on the motor, we do use a standard motor which has N.E.M.A. mounting dimensions, and I am sure that you can look forward to the gear manufacturers getting together and standardizing in much the same way for those applications where the gear case has supporting feet. I think it is fair to say that we must come to some such standardization, such as was found desirable in connection with motors.

Then Mr. Schaeffer brought up this question of gear rating and motor rating again. I will say that we have not, to date, in any case that I know of—and we will not in the future—put gears into a gearmotor which will not transmit the full torque of the particular set of motor parts that are chosen, be that a general purpose motor or hoist motor, totally enclosed, fan-cooled or what have you. A very good way to pick either speed reducers of the old type or gearmotors of the new type, where the gearing parts are not very definitely tied down to motor size, would be to find out what the pull-out torque of the motor is and then to pick gears which had an overload capacity that was equivalent to that pull-out torque of the particular motor used. Now that pull-out torque on the motor parts is not a constant figure, it is not always one and three-quarters, it is not always two, it is not always three, not always four, and some of the D.C. machines have very high pull-out torques and when you are in doubt, if you will take the figure that is given to you by the motor manufacturer as a pull-out torque for that motor, and then select your gears accordingly I am sure that where the manufacturer does not do the selecting for you, you can select the parts which will carry the loads of the motor. We try to do that for you, and that is the only point I have to make in connection with all this rating discussion. We appreciate when we definitely tie gears up to a motor, it is better, since we know the possibilities of those motor parts so well, it is better for us to do that work and do that selecting than it is to pass the problem along to the field men or to the purchaser.

Mr. Gale brought up the question that the applications seem to be unlimited. I just showed you a few of the applications that have been made and, as he said, the field is unlimited.

This question of series motor applications I am sure is somewhat covered by the statement that I have made that we will not put any gearing parts in connection with a set of motor parts unless they will carry the full capacity of the motor. I just want to say at this time that last May, I believe it was, we presented a paper to the American Gear-Manufacturers, trying to initiate the work of bringing these fundamental principles, that we have talked about tonight, particularly before the gear manufacturers, and requested them to appoint a standardization committee who would work out a standard procedure, or standard practice sheet, if you wish to call it that, so that we would all be talking the same language. I think that is highly desirable and I think if the purchasers push the A.G.M.A. far enough, I think we will get it; we have seen it in other industries. I attended an A.P.I. convention in Chicago, where they were praising the work of the N.E.M.A. insofar as they have gone, and calling on the Gear Manufacturers' Association to do some of that same type of work along the line of standardization, not only of design and dimensions but also of practices, and I think it is a question worthy of your continual support, and don't let it drop just because we don't all use the same method of rating; keep after it, and I am sure that the gear manufacturers can find a way to get together.

With reference to the question Mr. Flagg brought up in connection with the load-carrying capacity and so forth, stored energy values and so on, I might say that in order to make proper application of either motor or set of gears to any particular system, it is necessary to have a pretty definite idea

of what the system is made up of, not only the motor parts and the gear parts, but also the flywheels and the connected load, and I find it very helpful in some of these applications, to refer to our general engineering department who have a large number of curves on the various types of applications, and whether it is the coal industry, or the steel industry, or whether it is a hoist problem or an oil field pumping problem or whatever it is, we can find just the type of and cycle of operations that you get on that particular application, and we can do this job of putting gears in which will take the full capacity of the motor.

We are interested in this question of reversing drives. We have built some of these sheet catchers that you are familiar with in the steel game, and there you get a large number of reversals per minute. One of the units we designed was, I think, as high as forty reversals per minute and, naturally, the frame size was quite large as compared with the normal rating for that particular frame chosen, and so were the gears.

We do not recognize any groups of application, such as the general purpose group and the special purpose units and the heavy duty units, only because of this method by which we have put the gearing parts together with the motor parts. That is the only reason; you won't find in our literature but one set of gearing parts recommended for one set of motor parts, and I might say that it is not always because we don't agree that for many applications you can use gearing parts which are less capable of carrying the load than the gears that we provide in our units. When the development started we made a very detailed survey of just the number of sizes and the number of types of units that we should build to cover the gear motor field and it was economy, the economics of the development, that led us to seriously consider this building of only one set of gear parts for a particular set of motor parts. We could build all kinds of variations, of small motors and of big geared units, if we cared to—we are certainly equipped to do that—and part of the reason for doing the job just as we have done it was because of economy, and then after we got into the problem more thoroughly we realized that in buying a gearmotor for an application today you don't know that you are going to keep that gearmotor in that same application next week or next month. Many of the applications have already been changed, the gearmotors moved from one application to another, the speeds have been stepped up or stepped down, and so my advice is to buy the gearmotor so that you can move it from one application to another and not have to worry about increasing the size of the gearing parts, but let the original design take care of the maximum capacity of that motor.

Then the question was brought up, by Mr. Schnure I believe, about lubrication. The whole secret, of course, is not just in the fact that you use this particular type of oil seal that we use. There are many other types, and the amount of spring pressure that is used, if you use that particular type, the grade of the leather, the finish on the shaft and the fact that you have a space behind the oil seal, or between the oil seal and the bearing, and a return groove which drains most of the oil that goes through the bearing back into the gear case before the seal must become effective, all have to do with this question of lubrication and I don't want to tell anybody that just the fact that you use this particular type of oil seal means that it is going to lick your problem, but I will say that of the two thousand applications that we have made to date, we have absolutely no case of any oil getting into the motor parts. I should think that was a preety good record, in view of the fact that motor manufacturers themselves and motor users themselves, have had trouble with the oil from the bearings of the motors getting on the motor windings long before they began putting gears very close to the motor winding. I think our record there is outstanding. We will just pass it along to you as our experience.

Then the question came up about spares. I am glad that question has been raised tonight because I didn't appreciate the feeling that somebody might have in connection with spares. I will say that for the three types of units shown on the first chart, single reduction, type S and double reductions, type D and FD, we have used the same motor parts. The shaft extension for the pinion, the high-speed pinion, which is mounted on the motor shaft extension, is designed so that regardless of the type of unit that you have, our company has exactly the same motor parts. We carry those motor parts in stock and I don't think it is necessary to have any more difficulty to get motor parts for gearmotors than it is for the motors themselves. It is certainly not as complicated a problem as where you have motors and separate speed reducers. I think that is true, and in any analysis you make, get into it with the manufacturer and find out just how far he has carried his standardization program and you will probably come to the conclusion that there is a great deal of standardization that has already been done and that your cost of spares will not increase and, if anything, it will decrease.

Then this question of feet on the gear case only, came up, where the gentleman mentioned that insofar as he was concerned he would like to see the feet on the gear case only, and I would just like to point out the fact again that if you desire the feet on the gear case you can always have them there, regardless of whether you want the maximum ratio built into that case or any lesser ratio, because once it is determined that the maximum ratio for that case is forty to one, you can get all the way down to one to one in that same gear case, and if you desire the type where the feet are on the gear case you can certainly have it.

This question of oil seals and feet on the gear case has kept continually coming up. The Philadelphia Gear representative was stating that it might be possible to pick the gears for the largest ratio and, thereby, get the maximum strength in a gear case, regardless of the fact that you had a less ratio than the maximum. That is true. If you have twelve to one, for instance, we will give you exactly the same set of parts that you would if you had forty to one, in the case of our FD type of construction and at twelve to one you will have a reserve capacity over and above all the reserves that we have already built into the unit for the maximum ratio of forty to one, and that is why I say that part of the problem is a matter of economy with us, having the fewest number of parts to cover

this field and you will certainly get greater factors of safety in our gearmotors today than you did in the separate speed reducers.

Mr. Miller brought up the question of temperature on shut-downs, when the mill was shut-down and there might be some hot steel close by, and I can only say that if you will tell us of those problems, I am sure we will be able to make the proper recommendation for proper lubrication because of the fact that we have been supplying speed reducers to industries, every industry that I know anything about, for a long time and we have collected data that is necessary to solve those problems for you.

This question of the proper type of lubricating seal at high speeds: again I say, if you have high-speed applications, tell us about them and we will be glad to work with you on the particular application of the type required.

Then another question was raised on the average savings in percentage of cost. I didn't say much about the savings in percentages of cost because of the fact that there were some cases where we took the standard price forms of the motor, coupling and speed reducer and bed plate, and can show very high savings on a particular rating that would not be true at some other rating. I would say that, on the whole, I believe you can assume that you are going to save at least ten to fifteen per cent in first cost; you are also going to save a thing which is intangible insofar as we as manufacturers are concerned, and that is the saving in cost of installation and maintenance cost. We can't tell you exactly how much you are going to save in installation cost because we don't know just what type of installation you are going to have, but I think you can be sure of saving ten or fifteen per cent in first cost, plus all the economy of installation and maintenance.

The question of cast iron being used in the gear cases brings to my mind the fact that I didn't mention that some of the special gearmotors that we have built today have had fabricated cases. The only reasons we use cast iron is because, where you are building a large number of parts of the same design, and you are going to carry stock, the most economical gear case is the cast iron case. Now, where you have special designs and you are only going to build a few of them, it certainly is worth your while to consider fabricated cases, and we are equipped to build either type and we are recommending the type that happens to fit in best on a particular application when the question is raised. The only reason, as I say, for having our standard cases cast iron is because it is in high quantities and we get the lowest cost by using the casting. Now the design dimensions are slightly different, the wall thicknesses and weights are slightly different for fabricated cases than they are for cast iron cases.

Then the case came up in connection with other than A.C. motors. I didn't point out as we went along, but one of these particular installations that we are interested in these days, is in a brewery, which had two gearmotors in line, a small one and a larger one. One of those was a D.C. gearmotor. We are building quite a few of them. We put in an installation for the Navy Department, where we had a large number of units all the same, with D.C. motor parts. We care not what type of motor parts you want, just tell us and we'll supply any of them.

Then Mr. Lucas raised the point as to whether there is any heat difficulty, any difficulty from heat transfer to the motor, and he stated they chose fifty per cent higher rating for gears.

I have had quite an interesting time in the last year in trying to work out some of the problems of rating in speed reducers in the oil industry, and the men in the oil fields think that their problem is far worse than any steel mill problem. We are all inclined to believe that our problem is the hardest and they think that in the pumping well where they have vertical small diameter holes and are dealing with something down beneath the ground and have no good way of measuring the load, they ought to have factors of safety in the design far greater than you men think of in terms of steel mill applications, and they have been trying to point the way to the proper method of selecting speed reducers for the oil industry and we have been able to do some very good work in connection with the American Petroleum Institute, and we hope to do a great deal more, and are trying to do the thing that Mr. Lucas found it desirable to do in his case. If he found it desirable to use fifty per cent, I'll tell Mr. Lucas that there are some applications that he may bump into where he will want more than fifty per cent, and I don't know anybody that is better fitted to visualize what you will bump into than the group of designers who are designing the motor and the group of designers who are designing the gears, and it is only when they go hand in hand and work together that you are going to get the most for your money and that is just exactly what we are trying to give you.

I want to point out the fact that we are not the only ones thinking in these terms today, and I am going to quote—I haven't received permission from the Houghton Company to do this but I don't believe they would object to us reading from the Houghton Line," I just want to read you one paragraph and tell you that that is my story in connection with gears. This was in connection with belts. They say: "The belt man should proportion his belt drive to suit the performance of a motor. If he installs a belt not capable of transmitting all the power the motor can deliver, even for short intervals, he is simply headed for trouble." And that is my closing remark in connection with gear motors, that we are trying to solve that problem for you and, to date, we have been able to do it. I hope we can continue with the very fine experiences that we have had in the installations that we have put in to date.

H. K. Hardcastle: Mr. Marthens, I believe you overlooked answering one of the questions which was how you took care of the end thrust on the anti-friction bearings due to the use of helical gears.

R. S. Marthens: Oh, I beg your pardon. That question did come up. I meant to point that out when I said that practically all the gear manufacturers have standardized on the use of anti-friction bearings and single helical gears for the gearmotors. I am a little bit cocky about that, because that has been our practice on speed reducers for quite some time, even before gear motors came in. On the low speed set-up of our double reduction gearmotors we use a low helix angle of approximately fifteen degrees. The fact that they have the helix angle develops an end thrust of about 25 per cent of the

radial load and in the case of the high speed end maybe it is 20 degrees helix angle, and there the end thrust may go up to 30 per cent, approximately, of the radial load. In all the anti-friction bearings that we have picked, we combine the end thrust load and the radial load in selecting the bearings and there is no question about the capacity of the bearing selected to take both the end thrust and the radial thrust. On top of that we balance the helix angle so that the one set tends to make up for the other set, and the only load that is transmitted to the bearings then is the difference between the two, and there certainly are factors of safety in the design. You remember, you men who have been working with Timken bearings, and some of the other manufacturers of anti-friction bearings, Timken Company always told you if your end thrust is not greater than 25 per cent of your radial load, just to neglect it; but in selecting the bearings for our gearmotors, we took both into consideration and picked a larger bearing because of the fact we had included in our calculations both the end thrust and radial load and then selected for the combined load from their catalog, with the factor of application that was required for the story which we developed of gearing parts good for all the motor parts and are good for any type of application.

Were there any other questions that I neglected to answer?

W. F. Frank: What about this question of the two shafts on the same center line?

R. S. Marthens: Why, I think that's highly desirable on the double reduction units that we showed tonight, to have the shafts in line. I meant to mention that when I mentioned the fact that you can get the feet on the gear case from any ratio up from one to maximum. All the double reductions have the shafts in line. Remember, I showed pictures of two types of gear cases for double reduction, one where the diameter of the gear case was approximately the same as the diameter of the motor and I mentioned the fact that the output shaft was in line with the motor shaft. That same thing holds true on the type FD as I called them, which has a maximum ratio of 40 to 1. The output shaft is in line with the motor shaft, and I agree with everybody that that is a highly desirable arrangement. The only thing then you need worry about in dimensions is the fact that the dimension from the center line of your motor to the center line of your output shaft may vary with various manufacturers.

E. P. O'Neill: In regard to the oil seal used, have you any data on maximum temperatures and maximum shaft speed allowable?

R. S. Marthens: On that I will say that I would rather you would get that from them. They don't have only one oil seal and that's the reason I prefer that you get it from them. If you took my figures, you might assume that the standard oil seal that they market would be everything I say a seal of this type will do. They have various types of oil seals, depending on the particular application.

The maximum we have run into, I think, to date has had something like 2,000 feet per minute on the shaft. I am not sure of that figure. I think it is 2,000 feet per minute, and the maximum temperature that we have measured on gear cases ran about 225 degrees—the hottest spot in the gear case.

A. J. Standing: On this lubrication problem, both you and Mr. Flagg talked about in-door and outdoor conditions. Your answer was to give you our problems. Well, suppose I give you a set of specifications in the line of Mr. Miller's suggestion: you will start your mill Sunday night at six o'clock; the entire mill may probably be sub-zero and, within an hour or two, if you should have a power failure, as Mr. Miller indicated, you would go from that temperature to a temperature adjacent to 1800 degrees steel. This gives you a range to figure on.

In our two failures of worm driven units, one has been on the open hearth door where the whole drive is mounted, on the top of the open hearth furnace. That failed due to stiff lubricant in the worm drive casing. The other failure was on the ladle crane itself.

R. S. Marthens: Both of those cases were worm drives?

A. J. Standing: Yes. So it is hard to state a definite problem for you. We have that range to contend with.

R. S. Marthens: I don't think you will find the problem nearly so acute when you get away from the worm gearing. The heat generated in a worm gear, of course, because of the rubbing velocity in the worm wheel, is high, there is no question about that. You do not have that same problem. If you can visualize that your gearing efficiency may be fifty or sixty per cent—and that is the figure I didn't mention this evening—while the efficiency of the drive such as pictured here tonight is anywhere from 96 to 99 per cent, so you just don't have the heat generated inside the gear case with this type as you do with the worm gearing. As to whether you can go with one grade of oil from sub-zero to 1500 degrees, I don't believe we have any experience in gearmotors over that complete range for one unit. However, I think that we have sufficient experience that we have accumulated over years, to answer even that question. I believe if you gave us that problem as being one that you are faced with and wanted to buy one of these kind of gearmotors, I think we can work it out for you. I don't know of any application to date that has that wide a spread in temperature, however.

Design and Lubrication of Mill Reduction Gear Units

By THOMAS HOLLOWAY
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Paper presented before Mechanical and Lubrication Engineering Divisions of A. I. & S. E. E. at the 29th Convention held in Pittsburgh, Pa., October 17, 18, 19, 1933.

A thorough study of the subject of gearing is somewhat outside the scope of the engineers who purchase new gear equipment because it is, in many phases, quite intricate, and much specialized study is necessary to obtain a thorough understanding of the problems involved. And since the drive gears of a machine are often only a small part of the whole, it has been left to the manufacturers to specify the type and size of gears used.

T. HOLLOWAY

The differences of opinion between various gear specialists and the wide variations which frequently take place in their proposals has confused many prospective purchasers, and it is the object, in presenting this paper, to explain simply and by illustrations, the most important points of design and manufacture which influence the performance of gears.

The most common cause of trouble with gears is inaccuracy of manufacture, due to the use of obsolete machinery and methods. A secondary cause is faulty design and, occasionally there is incorrect lubrication.

It is well known that the increasing use of 60 cycle current and the higher efficiencies obtainable with high speed motors encouraged most purchasers to favor the development of high speed mill gearing, rather than that of the low speed motor, and it is recognized today that the developments made, have been on the whole, successful, and that as a consequence the trend of motor design is more toward the high speed motor, rather than to the direct connected slow speed motor.

The success that has been attained is due to unceasing improvement in the machinery for cutting rather than to any addition to the theoretical branch of the subject. The theory of gear tooth forms, the advantages of certain tooth proportions and pressure angles has been known and published for over a century, but the machinery for reproducing the correct forms has necessarily been more slowly developed, and it is only during the past fifteen years, and particularly the last decade, that gears have been placed in service which closely comply to theoretical requirements. Broadly, there are two methods used for manufacturing gears, namely, forming and generating. The generating methods may be still further divided into hobbing and shaping, both of which methods produce an accurate and silently operating gear provided reasonable care is exercised in the machine shop. With the forming method, which includes the use of end mills, rotary milling cutters, and template planers, there are so many difficulties encountered that they should never be employed for high speed gearing. It is obvious that any forming tool must be designed to represent the true tooth form when it is the correct relation to the gear blank and the many difficulties of maintaining this relation around the periphery of a gear are apparent. The cutting edges become dull long before a gear is finished, necessitating resharpening and providing opportunities for error both in grinding the contour and resetting. In addition, since this method was in use before the development of the generating methods, most of the equipment is old and of very light construction, and the dividing wheels of inadequate diameter to ensure correct tooth spacing. There are, however, some mill applications such as large blooming mill pinions where the cost of generating equipment is high compared to the total number required, and in these cases forming tools are most commonly employed. There are indications, however, that even on this class of equipment they will be generated as soon as there is an accumulation of the necessary cutting tools.

To discriminate between the hobbing and shaping methods is not easy because both processes have been developed intensively in the last few years, and it is probable that the critical advances in each method are known thoroughly only to the specialists in each branch. It is clear, however, from observation of drives and miscellaneous gears in the field that the standard of accuracy has greatly advanced and that 1 D.P. gears now have only about .001" or .002" inaccuracies of contour and division which is about the best obtained with 3 pitch gears ten years

ago. It can be further stated that the shaped gear is more valuable for universal application than the hobbed gear, because of the continuous form of tooth. Unquestionably, the continuous tooth is an advantage in mill pinions, because of the saving of bearing face, and the increased resistance to bending and torsion; the same advantages apply to all pinions of small diameter, and to gears of narrow face. Theoretically, the shaped gear should be more accurate because actual running conditions between pinion and gear are more nearly resembled during the generation. The shaper method employs a master pinion cutter which is itself an original gear, so that identical conditions are obtained between cutter and blank as between pinion and gear, but the gear generated by a hob seldom meshes with a single helical pinion with its axis inclined to the gear. It is also to be noted that the shaping process is a later development of the art than the hobbing process as the hobbing process was of forming.

(A more detailed explanation of the shaping generating system was given with the aid of a diagram of the machine elements and some moving pictures of a large machine in operation.)

There are a number of points of gear design which are generally raised when new installations are being discussed, such as the various merits of straight tooth, helical and herringbone gears and the proportions selected which will stand some discussion even at the risk of being platitudinous. It is assumed that the involute gear only is referred to. While the cycloidal gear is still occasionally used, and in certain cases advantageously, practically all gear cutting equipment existing is designed for involute gears and to include a discussion of cycloidal tooth forms would hardly be profitable.

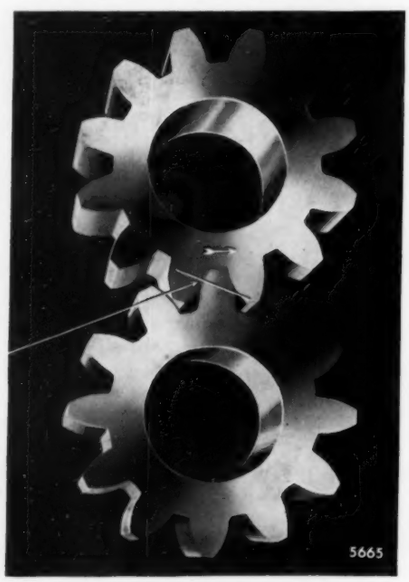

FIG. 1

Tooth Engagement of Spur, Helical Spur and Herringbone Gears

It is difficult to generalize upon the merits of different types of involute tooth form design for parallel axis. There are, however, definite characteristics of each type which irrespective of proportion remain constant.

Straight Tooth Spur Gears

When a load is applied to a straight tooth gear it is effective on a line parallel to its axis, but during various phases of tooth engagement there is an uneven number of teeth which share the load; consequently, at different parts of the tooth contour the load is unequal and this results after a period of

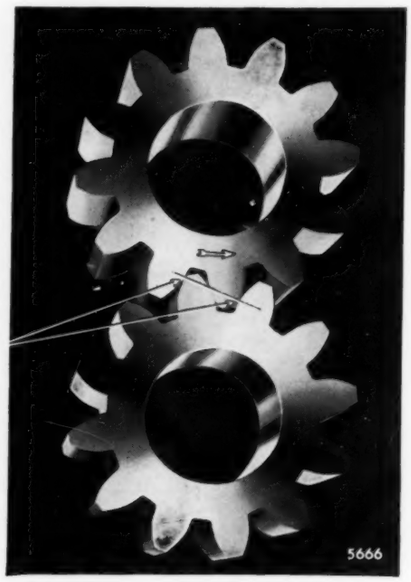

FIG. 2

years in uneven wear and consequent interruption in the transmission of uniform angular velocity. In other words, the true theoretical contour of the tooth is mutilated during service and there is consequently noise and vibration present. Figures 1, 2, 3 and 4 illustrate this point. One illustration shows a pair of spur gears marked with the line of action along which the pressure is applied when only one tooth is in contact. Another illustration shows the same spur gear with two teeth in contact. It will be obvious that the load of a spur gear greater at the center of the tooth than it is at the tips and roots. This condition can vary in intensity according to proportions, but it remains an inherent characteristic of the spur gear.

Helical Spur Gears

Helical spur gears really consist of an infinite number of spur gears arranged so that the teeth trace a helix. The line along which the load is applied, which will be seen from the illustration, is oblique to the axis and stretches across the face from the roots to the tips of the teeth. The load is, therefore, uniform from root to tip and this type of gear has a tendency, when it wears, to wear evenly over the entire height of tooth and to operate smoothly even after long service. The multiplicity of teeth in contact at one time eliminates impact loads and renders the motion smooth. There is the disadvantage, however, that to obtain really smooth action, the

FIG. 3

helix angle must be relatively high and this causes an axial thrust which is often inconvenient.

Herringbone Gears

Following closely the discovery of the single helical gear came the introduction of the double helical gear so that the end thrust could be avoided. At that time there was no machinery for producing double helical gears with cut teeth so that the first herringbone gears had cast teeth.

It is interesting to note that all of the cast tooth double helical gears had continuous teeth and a relatively high helix angle.

The general practice for gears in the early development of gear cutting equipment was mainly the machine cut spur gear in preference to the single or double helical gears, but in 1902 machinery was invented for cutting the two helices simultaneously so that there was a great reduction in production costs and since that time herringbone gears have been an international standard for heavy duty and high speed work. There is one European maker that specializes in straight tooth gears for high speed work but there is so much more skill and care required to produce a straight tooth gear which will run silently than there is a herringbone gear, that there is really nothing to justify the use of the straight tooth gear

There are conflicting opinions as to the proper helix angle. Theoretically, the proper helix angle is the highest angle which can be selected with the normal thickness of the tooth remaining thick enough to properly support the load, but since manufacturing considerations, such as the high tool cost, enter into it, a compromise is generally adopted.

For high speed gears operating at pitch line velocities between 5,000 to 14,000 F.P.M., 45° is probably the best angle to use. The angle is large enough to obtain a great multiplicity of teeth in contact and in most cases the tooth loads are low enough to permit the reduced normal thickness of the teeth. For general mill practice, however, 45° would prove entirely unsuitable. It would be satisfactory for high speed main drives and for the light auxiliary drives used on accessory equipment, but would not be suitable for mill pinions and sheet mill drives operating with heavy flywheels. It is generally acknowledged that the use of an angle of 30° does not have these limitations and is very satisfactory for all classes of

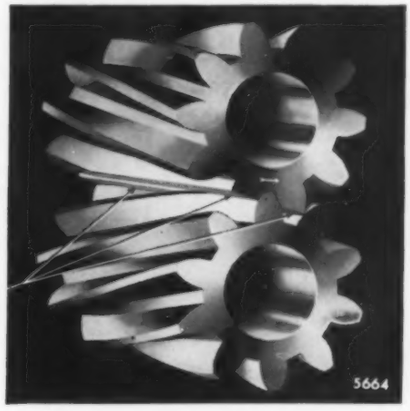

FIG. 4

mill gears where the herringbone type is used. The angle of 23° at one time most generally used, was merely selected for manufacturing reasons; the design of the hobs being most convenient for this angle, and the accumulation of tool stocks has resulted in its continuous use.

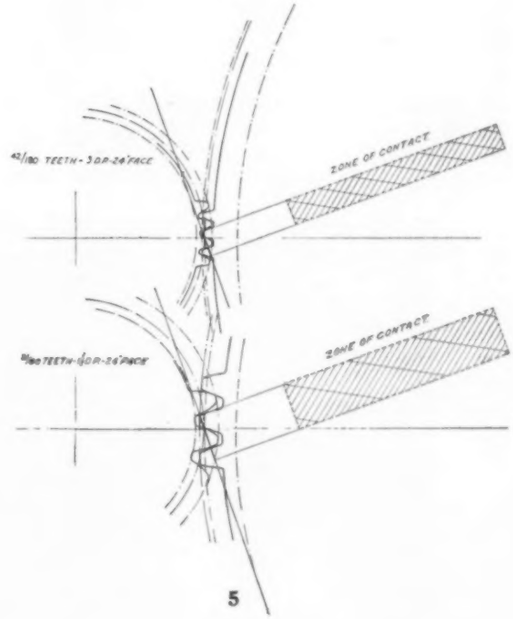

FIG. 5

While on the subject of helix angles, there is the controversial point of pitch and number of teeth. It is an increasingly popular practice to employ much finer pitches for drives on cold mills than was formerly considered correct design. It is quite common to find reel drives and main motor drives with powers as high as 1500 H.P. with gears having only 2 D.P. or 2½ D.P. and while, of course, there is a

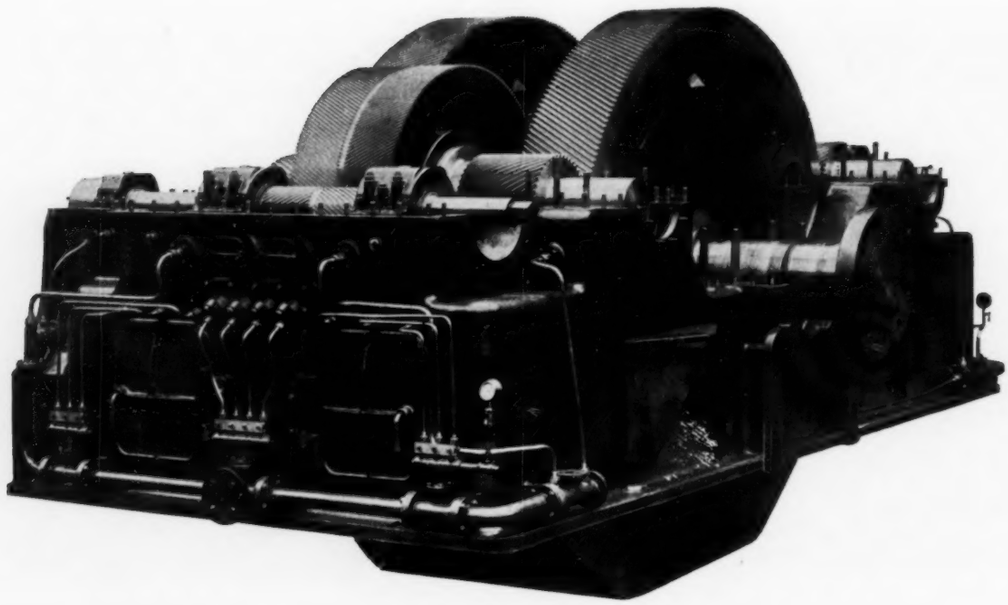

FIG. 6

limit to this practice, there is a good deal of logic in it. We illustrate (Figure 5) a comparison between two pairs of gears both operating on the same center distance with the same base circles, the same pitch circles and the same pressure angles, but one pair having 21/90 teeth, 1½ D.P., and the other pair having 42/180 teeth, 3 D.P. which is, of course, half the pitch.

The arc of contact is shown for each case and also the zone of contact to the center of the apex of the teeth taking a 24" face. From this it will be observed that for the best condition of engagement, there are five teeth in contact with the large pitch gears and eight teeth in contact with the smaller pitch gears. While the width of zone of contact on the 6-pitch gears is smaller than that of the 3-pitch gears, the reduction in the base circle pitch and the greater number of teeth in contact, almost exactly balance so that the lengths of the lines of contact if totaled in each case are practically similar.

It is clear that providing the pitch is not reduced so much that the normal thickness becomes so thin that excessive deflection takes place, the fine pitch gears should have equal load bearing capacity to large pitch gears of similar diameter and should run more smoothly. This single diagram is merely touching the subject. Many different results can be obtained by fluctuation in helix angle and by the use of

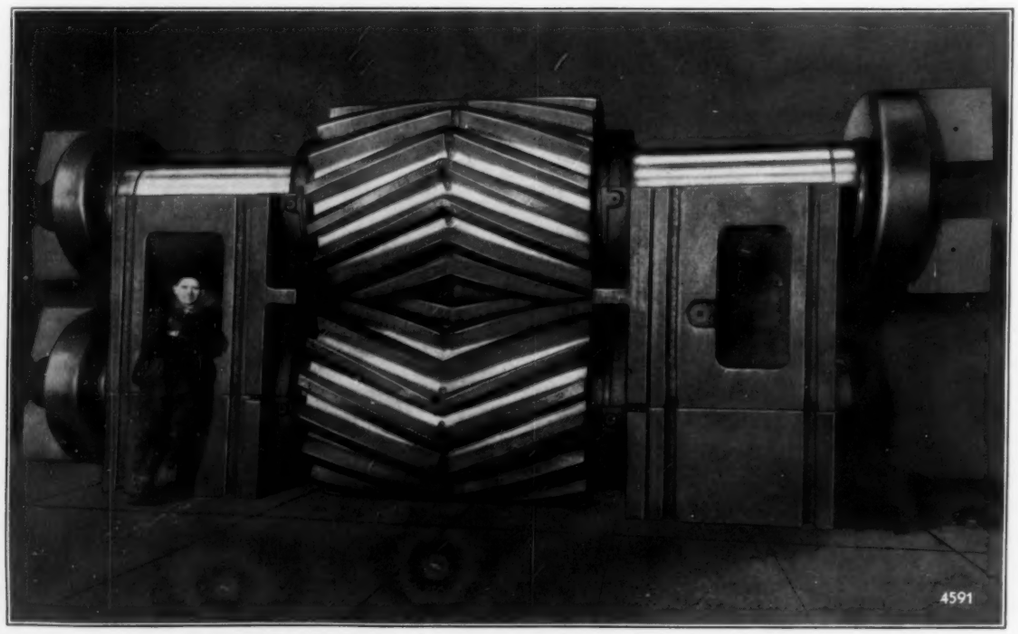

FIG. 7

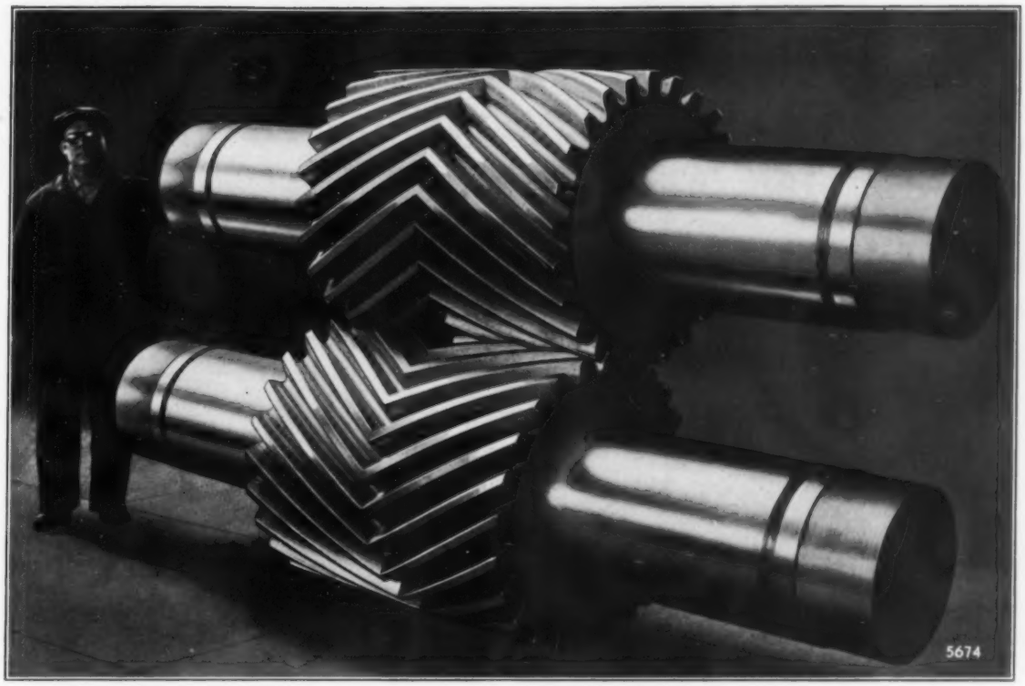

FIG. 8

special proportioned teeth and a full development of this idea is hardly within the scope of this paper. The best practice in cold mill work at present discloses the most common use of 1¾ D.P. and 2 D.P. gears for main drives and from 2 D.P. to 2½ D.P. for reel drives.

Before proceeding to a further consideration of gear tooth proportions, there are three illustrations which have a bearing on that part of the paper already read. The first illustration (Figure 6) shows a typical double reduction high speed turbine gear with 30° angle. The pitch of these gears is very fine considering the commonly accepted practice for mill work and it will be noticed that the general design is different from that in general use in mill work; that is to say, the first reduction gears are made in one piece and the low speed gears are divided into two sections. General mill practice is to make the high speed gears in two sections and the low speed gears in one piece. It is difficult to account for this latter type of design. It is obviously more easy to make gears accurate when made in one piece and it is the high speed set which requires most of the care. The loads on the intermediate shaft with the type of design illustrated are heaviest at the ends where there is proper support from the bearings and the load in the center of the shaft is very light. On the other hand, there is an exact reversal of conditions with the standard mill type drive. Presumably this design has been most commonly used because of the convenience of distributing the flywheel loads, but it is really quite a simple matter to apply flywheels in either case in satisfactory manner and there are so many advantages with the design illustrated that it should be more popularly used than it is at present.

The next illustration (Figure 7) shows in contrast to the high speed turbine gears a pair of large blooming mill pinions which were template planed. The necessity for accuracy with these gears is, of course, not comparable with the high speed set so that the forming system is permissible. However, as stated before, there is a trend towards the generation of even these large pinions and the next illustration (Figure 8) shows a pair of 36" blooming mill pinions cut with teeth having a total inaccuracy of .003".

Tooth Proportions

A wide variation in load carrying capacity may be obtained with the proper selection of tooth pro-

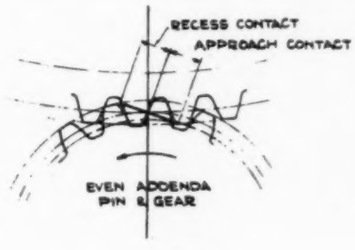

FIG. 9

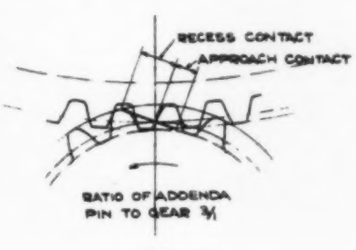

FIG. 10

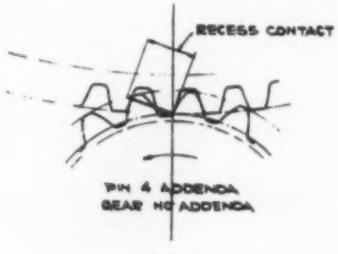

FIG. 11

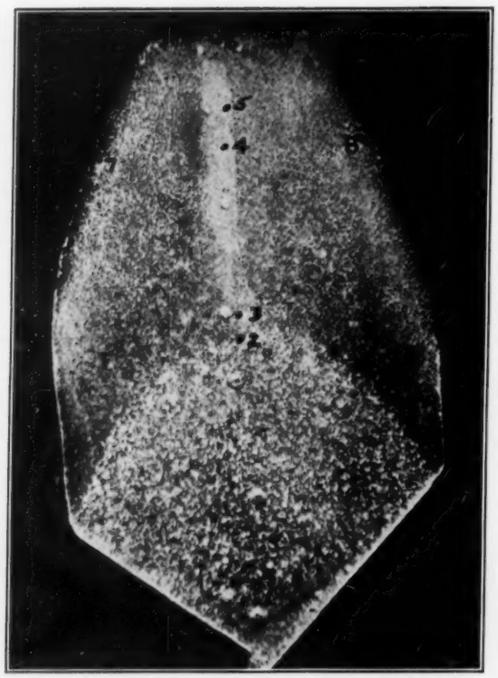

FIG. 12

portions. It is often possible to quadruple the capacity of a set of gears generally described as standard by making the working depth, pressure angle and helix angle to suit each particular condition. Generally most gears do not require special depth, but practically all gears are better with uneven addenda between pinion and gear.

The first illustration (Figure 9) shows a pair of gears with 19 and 90 teeth meshing on standard centers. The second illustration (Figure 10) shows similar gears with increased pinion addendum and the third, (Figure 11) gears of exactly similar teeth pitch and pressure angle but with the whole working depth of the teeth above the pitch circle of the pinion and the gear with an outside diameter equal to the pitch diameter. It will be seen that in the first case the approach contact and recess contact are about equal, but from the second and third diagrams that the approach contact decreases and the recess contact increases as the addendum of the pinion is increased, until, in the third case all contact is recess. During approach contact the teeth are moving against each other and during recess they are moving away from each other so that it has been generally considered that there is more friction during approach than recess and, therefore, gears with the greatest recess contact are the most efficient. There are two other changes that occur with this increase in diameter that are not so apparent. The base circle remains constant in each case so that the same involute is used, but as the diameter increases a different section of the curve is used, and it will be noted that the average radius of the curve increases with the diameter. Consequently, pinions with increased addenda have greater resistance to pressure than standard pinions.

A comparison between Figure 9 and 11 shows the average radius of the pinions to have been doubled while the gear contour is unchanged, so that if it is assumed that gear teeth are similar to two cylinders under pressure the gears in Figure 11 are capable of carrying almost twice the load of those in Figure 9. Another change in tooth action occurs with the gears in Figure 11. It will be seen that the tooth contact commences at the line of centers and is all in recess. The teeth are, therefore, during all the period of contact, moving away from each other so that, since the direction is constant, the oil film is maintained.

With gears having both approach and recess contact the flow of oil is reversed at the line of centers and this leads to a breakdown of the film if the pressures are high. The writer has observed gears cut in this manner and in each case the teeth were

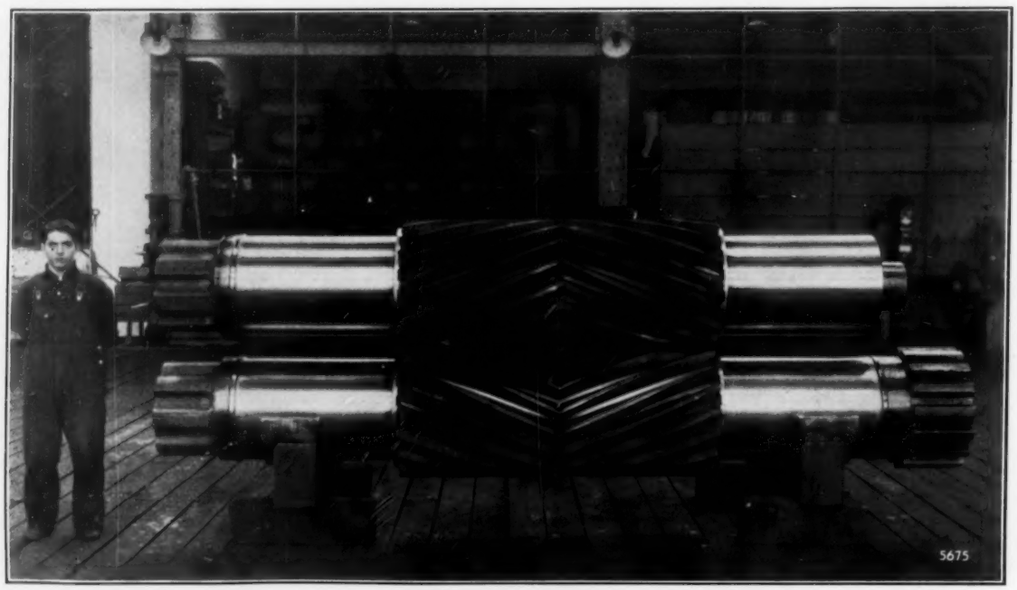

FIG. 13

highly polished and seemed to run more quietly than other gears.

This covers generally the method and the more common points of gear technique which it is impossible to write into the general specifications of a proposal. The next thing to consider is the selection of size, then the material, then the lubrication and from this data we can design the gear case. The first difficulty is to discover the exact load the gears have to transmit. The nominal horsepower of the motor tells us something and its characteristics tell us a little more, but to design gears of adequate size but not of excessive size, we must have the normal load, the peak loads and the duration of each kind of load. The mill builder has an advantage in this respect. It is obviously necessary for him to have an accurate knowledge of the work performed and having an intimate knowledge of the processing of metals can often foresee future changes which may be made and which should be considered in selecting the sizes of the driving mechanism.

Once the loads are determined it is comparatively simple to select gears of proper proportion when there is freedom of choice as to centers and width of face. It is generally best to use ordinary cast steel (about .35 carbon) for the gear and either a high carbon (.5%-.6% carbon) forging or alloy steel forging for the pinion. It has latterly become almost universal practice to use an alloy pinion heat-treated and tempered. If this practice is followed there is the possibility of increasing the horsepower capacity by changing the gears to harder materials without any change to the case, but if the hardest materials obtainable are used at the outset any increase in load means a completely new unit.

There are many places in a mill, however, where local conditions restrict the space available and hardened materials are essential. For a long time the best practice for high speed gears operating under heavy loads was to make the pinions of a good alloy (SAE 3145 and SAE 6145 were most commonly employed), quenched and tempered to the limit of machinability (about 275 Brinnell) and to make the gears of high carbon nickel alloy of about 220 Brinnell. It was held that although it was possible to quench after complete machining and obtain a hardness of nearly 500 Brinnell the resulting distortion caused the load to be taken on a few high spots where, of course, it became more concentrated, and the impact loads due to irregularities of alignment became greatly in excess of the normal loads. Also there was much noise and vibration. This practice has now been improved. Mill pinions and even large gears subject to extremely high tooth pressures are made of ordinary carbon steels, are finished completely to correct contour and are then hardened without distortion to about 475 Brinnell. The method employed is the local hardening of the tooth surfaces by means of an oxyacetylene torch followed by a water quench. The heat is concentrated upon only a very small section of the tooth at one time and is fed slowly along the face, each section being quenched automatically as the torch traverses. The result is shown in Figure 12. The tooth section is a magnification of a 2 D.P. tooth of about .45% carbon steel and the hardness readings are as follows:

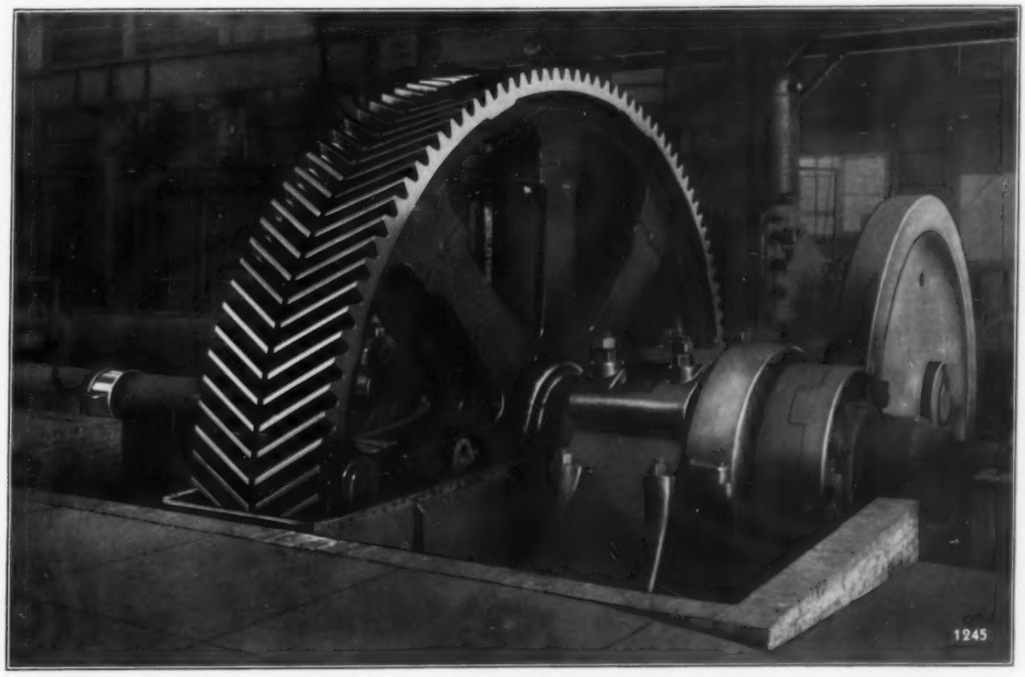

FIG. 14

1. 175 Brinnell
2. 200
3. 250
4. 444
5. 461
6. 477
7. 495
8. 477

There is also shown (Figure 13) two pinions

used for driving a finishing 4-high stand on a 96" continuous strip mill. The pinions have a pitch diameter of 25", 4.3633" circular pitch and 62¾" face. The teeth and splines were hardened to 475 Brinnell.

This method was originally used by Vickers, Ltd., in about 1910-13 but to the best of our knowledge was not extensively used until the last ten years except on small gears. It is now a highly developed system. A torch with a number of nozzles is held on a traveling carriage and the tooth preheated, quenched and tempered automatically at a uniform rate.

Lubrication and Its Influence On Gear Case Design

This subject may be treated either in a simple manner or in a very deep manner. It is a subject full of pitfalls even for the most careful investigator and it seems almost impossible to be as exact as the mechanical side of our problems. There are so many claims and counter claims of superiority of various products suitable for mill use that it is obvious that almost all must be good and that practically none stand out in advance of the rest. Indeed, the net result of hundreds of tests by roller bearing lubrication chemists is to tell us what is not suitable rather than what is the best lubricant to use. It was common practice up to about 1929 to 1930 to specify a good grade of mineral oil (about 2100 Saybolt at 100°) for large mill drives and a lighter grade for the bearings; the splash and ring oiling bearing system being the most common practice. There are certainly hundreds of these drives still operating satisfactorily under the same conditions and there is very little difference in the sizes of drives selected today than formerly.

It is, therefore, a very open question as to whether extreme pressure lubricants are of any considerable advantage on the majority of drives which are properly designed with correct materials and normal pressures although there is a gain where excessive tooth pressures exist. This condition is much better avoided, however, and it can generally be effected if sufficient care is taken in proportioning gears and in selecting materials.

It is interesting to note that extreme pressure lubricants became prominent at the time gear pressures on back axle gears were increased from 1200 to 1850 lbs. per inch of face and that so long as the extreme pressure lubricants were used the teeth apparently did not cut, but when ordinary service station grease was used the gears failed. It is even more interesting to note the behavior of a pair of mill gears at about the same time. These gears were made of alloy and carbon steels of about 36 scleroscope hardness and even though the heaviest grade of E.P. lubricant was used they scored and cut under the extreme service to which they were subjected. They were then re-cut and hardened to about 75 scleroscope, and placed back into service with the same lubricant. The teeth are now polished and look good for indefinite service. It would seem, therefore, that while there is undoubtedly differences in the quality of lubricants, there is not at present, sufficient accurate information available so that results can be predicted and that the best policy of the designer is to so proportion each set of gears that with the use of ordinary lubricants of reasonable cost they will operate satisfactorily.

FIG. 15

Next, there is the question of lubrication systems. The best system is the simplest that can be used successfully. For units with moderate pressures and of such proportions that the splash and flood system is practicable, this is the best to use. The same oil is used for bearings and gears and is continuously circulated by splash and gravity. With proper baffles and dust rings the loss is very slight and a filter unnecessary. Such drives should operate without attention for months. (Illustration of typical bearing, Figure 16). Drives with gears under heavy pressure or of such ratio that the splash is insufficient to flood the bearings should be designed for splash for the gears and ring oiling from separate reservoirs for the bearings but where the peripheral speed is 2000 ft. or over forced feed to the bearings and sprays to the gear teeth should be employed.

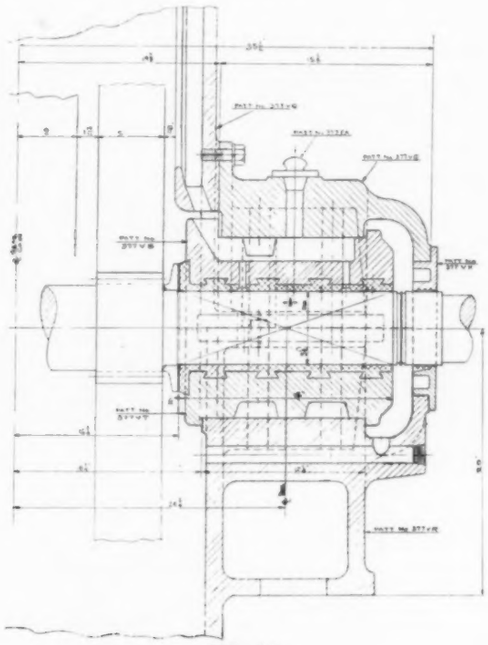

FIG. 16

There are several illustrations (Figures 16, 17, 18) showing typical bearings but since in addition to their interest from the lubrication viewpoint they have other features of interest, it may be advisable to digress slightly into general design. The first illustration (Figure 14) shows the main sheet mill drive at the Apollo Steel Company. The picture is familiar to most present but it is worthy of being shown again. It was installed over twenty years ago and was, to the best of our knowledge, the first drive equipped with two flywheels on the pinion shaft. This practice is now, of course, the recognized standard in the steel industry.

The next illustration (Figure 15) shows the drive for a roughing stand of a continuous strip mill. This drive is typical of modern construction, the main bed being of box section with openings on the outside for the circulation of air and the height of the bed arranged so that the top is on the level with the center of the bearings. The lubricating system is designed for separate lubricants for bearings and gears and it may be perceived from the photograph that there is a distinct line of color at the point of

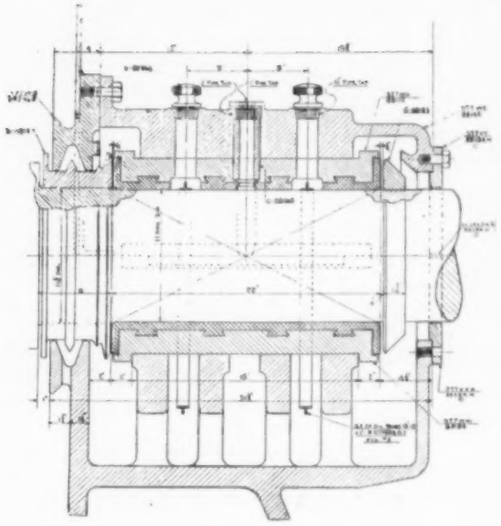

FIG. 17

the pinion shaft where the bearing and gear baffles separate the oil. This drive is one of ten of similar size connected to a central system containing about 4000 gallons of gear lubricant and about 500 gallons of bearing lubricant; the whole system being filtered by Centrifugal Filters. From latest information received, the separation of the lubricant is so successful that out of all this continuous circulation of over 4000 gallons of oil, during a period of 24 hours' operation, there is a maximum of two pails of foreign matter recovered from the filters. This foreign matter will include some of the heavy lubricant filler, some foreign matter, some water and some light grade oil so that the exact amount of interchange is probably less than two gallons for the entire ten units.

A recent design of bearing is next illustrated, (Figure 17) showing a successful method of oil baffles and the separate bearing shells from the cap and base.

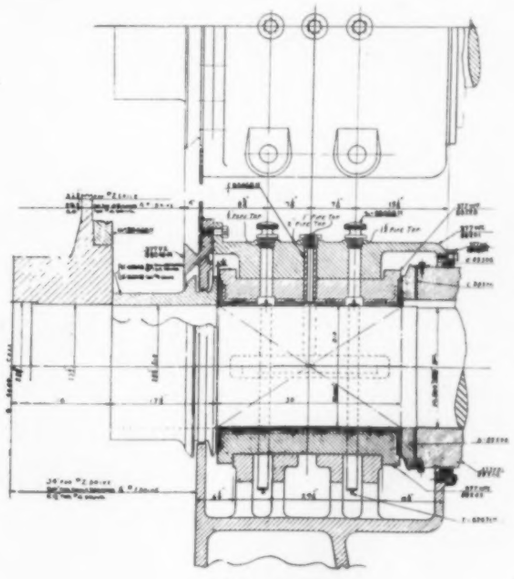

FIG. 18

The next illustration (Figure 18) shows a bearing of similar design but arranged with a thrust collar between the low speed bearing and the mill coupling. The arrangement of shims for bearing adjustment may be clearly seen. They are purposely placed inside of the cap so that there will not be too frequent adjustments made as have been made in the past

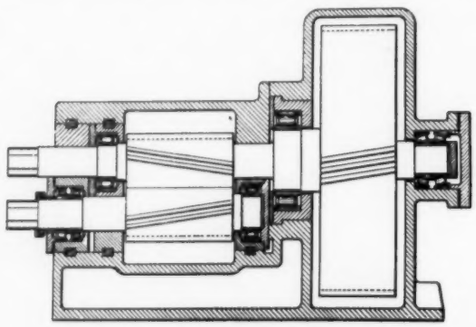

FIG. 19

with screw adjustments being provided on the outside of the case.

There have been several cases where unnecessary adjusting has caused trouble on the thrust faces of the bearings. It will be noted from the design that the bearing may be removed independently from the cover and vice versa. To return to lubrication systems, it may be said that where there are a number of gear units in close proximity and conditions of service are similar, it is undoubtedly more satisfactory to use one central system than to use individual systems. Better filters may be used with the central

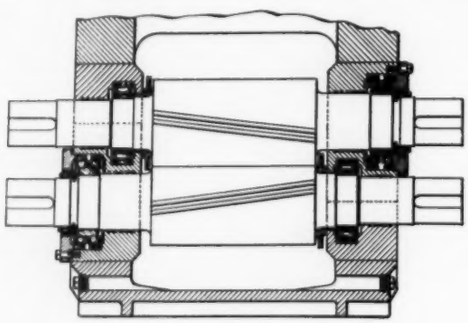

FIG. 20

system and duplicate pumping mechanisms, and due to the larger volume of oil continuously circulated throughout the entire system, the general temperature of the oil is lower. Most central systems are inexpensively equipped with coils so that they may be connected to the water system in summer and to the steam pipes in winter, but it is much more difficult to arrange this system of cooling and heating with individual systems for each unit. The influence that anti-friction bearings have on lubricating systems is well worth attention. The gear maker will almost invariably prefer the anti-friction bearing because a much heavier lubricant may be used in one central system than with plain bearings and the same lubricant can be applied to both bearings and gears. This removes the expense of complicated baffle arrangements and offers greater protection to the gears. Roller bearings are more satisfactory on gear drives because they are precision made thus necessitating accuracy of gear alignment which, of course, ensures perfect tooth action; and since they do not wear appreciably if selected with sufficient margin of safety, the gears are held in perfect alignment permanently.

It is sometimes difficult to arrange pinion stands for 4-high mills for roller bearing mounting due to the very small space between the necks of the pinions. There has been developed a design next illustrated, (Figure 19) showing the staggered arrangement, which is very ingenious. The end thrust from each pinion is taken on tapered roller bearings of adequate size and the bearings so off set that there is no more distance between the bearings than there would be with plain bearings arranged with baffles. The top left hand bearing housing is a duplicate of

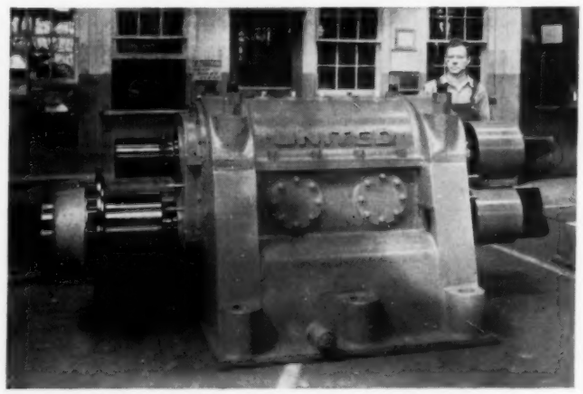

FIG. 21

the bottom right hand and the top right hand a duplicate of the bottom left hand so that the pinions may be turned around the same as if plain bearings were used.

A development of this principle is applied to a combination pinion stand and main drive for medium and small size mills. This arrangement is next illustrated, (Figure 20). Every bearing is amply large for the service, the shafts are adequate for the torque and the deflection between bearings is well within permissible limits.

Drives of this type are arranged for force feed lubrication from an individual system.

Welded Steel Construction

There is at present, a good deal of interest in the use of welded steel construction for machines and rolling mills and there are many differences of opinion as to the desirability of welded steel in precision machines such as high speed gear drives and heavy duty pinion stands.

A combination of welded steel plate and steel castings seems the best solution. The illustration (Fig. 21) shows a 20″ pinion stand which is a combination of steel castings and rolled steel plate. The two end bearing housings are made of cast steel and the side supports, the bottom plate, and the connecting walls of rolled steel plate; the cap is made from two heavy castings, one at each end, and 1″ plate as a tie be-

tween the two. The advantages obtained by constructing a pinion stand in this manner are:

First. There is very little possibility of defective material. The cast steel parts are large simple castings with no coring at all and the box construction obtained with the rolled steel plate enables minimum sections of the metal to be used with safety.

Second. There is a flexibility of design generally unobtainable with cast iron or cast steel construction. It is just as easy to design each particular pinion stand to suit individual conditions as it is to adhere to a standard design.

Third. There is a saving in cost, particularly due to the simple patterns involved and to the absence of any intricate core work. The stress relieving operation is also simpler than the annealing operation for a steel casting.

Fourth. A new field for rolled plates is created. There is a certain loss to the steel foundry of tonnage but this is not quite so serious as it seems because about 40% of the weight is cast steel and each piece is of very simple design and easy to cast, whereas, if the whole drive were made of cast steel, a good deal of core work would be necessary and with this there is always the risk of failure.

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Welded Rolled

By F. L. LINDEMUTH,
Chief Engineer, The William B. Pollock Company, Youngstown, Ohio.

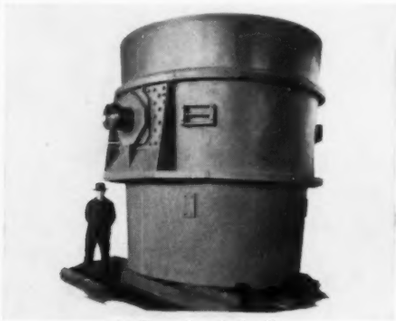
F. L. LINDEMUTH

One part of the business of the firm with which I am connected is the operation of what is called, for the want of a better term, a "welderie." Here we make welded parts, not only for our own products but for other manufacturers, in about the same way as a jobbing foundry makes rough castings for a machinery manufacturer. In this line of work we come into contact with many different ideas and have problems put up to us in many different ways. We will consider some of the questions which frequently come up.

Welded steel construction can be called "A New Deal". Like other "New Deals", we know it is a good thing and are for it, but it has not been in practical use long enough for us to say that all the bugs have been worked out of it, and that we know from experience exactly how to proceed in any given case.

The older arts of construction which employ casting, forging and riveting of various materials, each has its merits and also its limitations. We take advantage of the merits and accept the limitations, and unconsciously we choose our methods of fabrication and materials to get the results we want in the best way available. Economical shop methods and tools for various operations have been worked out by long experience. In a well designed and constructed piece of equipment the shapes and sizes of the various parts are not always what is required by a rigid mathematical analysis, but are governed somewhat by what is possible and economical in the manufacturing processes. When an expert looks at a well designed and well constructed piece of equipment, he appreciates not only the evidences of good craftmanship but the way in which the various parts have been worked out to suit the limitations of the various manufacturing processes.

Welded construction is in a stage of development. We have not accumulated enough experience to always say that certain constructions are best if welded and just how the welding should be done. We must scheme around a little to find out how to make each detail in the most satisfactory manner. The shop equipment available includes tools that have been developed with other kinds of work in mind, and the rolled sections used have been developed for riveted work. Our details are now being made to fit these existing machines and sections. As we go along we will probably find new and better ways of getting the results we want, and if new machines and sections are required, they will be forthcoming.



130-Ton Steel Ladle.
Welded Construction Gives Light Weight.
Annealed to relieve welding stresses.
Patented.

When a designer starts in to lay out a machine or structure, he pictures in his imagination about what the finished product will look like. With the older arts of construction this is not hard to do for he has precedents to follow. He now must imagine what these welded things should look like. One way of looking at this is that a piece of welded work, if used where riveting was used before, should look like a riveted job, and if used where a casting was used before, should look like a casting. In some cases this may be right, but in others it may not only run into needless expense, but forego some of the unique advantages that welded construction may have for the particular application on hand.

It is hardly necessary to say that a change to welded construction is justified only if the cost is less; or if the cost is the same it is better for some other reason; or if a result is possible that cannot be gotten in any other way.

In riveted work the joints are very conspicuous and comprise butt straps, clip angles, gusset plates, or lap joints, and the size of the connection pieces and the clusters of rivet heads are plain evidence of the size and adequacy of the joint. In welded work extra connection pieces are seldom necessary, and the only visible evidence of the way the joint is made is a small fillet of weld metal. A welded roof truss looks very different from a riveted truss. Sufficient welding is developed at the joints without the use of gusset plates, and the absence of large con-

Steel Products

Presented before the Welding Engineering Division of the A. I. & S. E. E. at the Twenty-ninth Convention in Pittsburgh, Oct. 19, 1933.

Gear Case.
Castings are combined with steel plate. Annealed to relieve welding stresses for strength and to prevent distortion after machining.

nection pieces gives it a rather odd appearance. If gusset plates were used and welding substituted for rivets to retain the appearance we are used to, we would have the extra cost of the plates and almost double the amount of welding.

With castings, the thickness of sections and the

Pump Frame and Base.
Box Sections give light weight with strength and rigidity.

shape and size is often determined by what can be done in the foundry rather than what is required for strength or other considerations. In welded work, the thicknesses in various parts of a piece can be kept to what is required for strength, and shapes and sizes are possible that can be gotten in no other way. For example, large thin walled box sections that could not be cast are easily welded. On the other hand intricate shapes with bosses and abrupt changes of section that are easy to cast may be laborious and expensive to weld.

In using welded steel, the designer should not be influenced by what it is possible to make in a foundry, but should consider rather the rolled sections available, what shapes can be formed and welded economically, and at the same time he should remember that many shapes and sizes can be welded that are not possible in any other kind of construction. A composite construction of small complicated castings or forgings welded to larger rolled steel members can often be used to advantage, as for example, cast bearings can be welded into a large plate or structural frame.

As we become more familiar with this style of construction we will not be satisfied unless we see that the design has been well and economically worked out and good craftmanship is plainly evident.

The tendency is to use too much rather than too little welding. A welded joint is inconspicuous compared with other joints, and unconsciously we try to build it up until we can see it better. The metal in the weld is expensive, and may cost from fifty cents to two dollars a pound for hand welding. In an economical job no more welding than is required should be used any more than more rivets than are necessary should be used in a riveted job. Excessive welding can run the cost up very rapidly.

As the weld metal solidifies and cools, it cannot contract freely and naturally, and stresses are set up in it. In some cases means should be taken to relieve these locked up stresses. One way to do this is to peen each layer of metal as it is deposited, which requires skill and judgment on the part of the operator. A more satisfactory method, when it is possible, is to heat the finished work in a furnace, a kind of annealing process. This operation may sometimes cost more than it is worth.

Proper stress relieving generally improves the weld, but is not always necessary. Large welds, say over five-sixteenths or three eights of an inch, are made in more than one layer, and the successive layers to some extent anneal the welds under them, which helps a little. An unannealed weld of any size has a very great amount of strength. When the stresses in a joint are high, it may be cheaper to make the welds a little larger to reduce the unit stresses in the weld metal and dispense with the stress relieving process. In some cases there is a chance of damaging the work by putting it in a furnace, for example, in a piece with both very thick and very thin parts. Before the thick parts are heated through the thin parts may get overheated and buckle, even with the most careful operation, and a buckle once formed is almost impossible to straighten. Aside from the matter of strength, if a piece is to be machined, and there is a considerable amount of welding not placed symmetrically, it may be necessary to anneal to remove locked up stresses which would pull the piece out of shape in setting up a new equilibrium after part of the metal is removed.

No definite rules can be given as to what should be stress relieved and what need not be. Consideration of the pros and cons must determine what is to be done.

The chief engineer of a large machinery building company told me recently he had heard a talk on welding, and what he had gathered was that there

Welded Spelter Pan has advantages over Riveted Construction.

were so many ifs and ands and buts and precautions to be used here and there and everywhere that he was frightened and would not try it in any of his equipment. It is not as bad as that. To get the best results in welding takes a little know how, the same as in fishing or cooking or running a machine shop. There are a number of good shops furnishing welded steel parts for machinery and other purposes who have accumulated a large amount of experience. If you are considering the use of welded steel and do not know exactly how to go about it, they will welcome the chance to go into the matter with you.

ITEMS OF INTEREST

PERSONNEL CHANGES

W. F. Detwiler who has been named executive vice president and elected to the board of directors of Allegheny Steel Company, Brackenridge, Pa., is an executive yet young in years, but with 26 years of continuous experience with the Allegheny company.

Prior to his association with the Allegheny company in 1908, he served a ten-year electrical apprenticeship with Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

W. F. DETWILER

His first job with Allegheny was as master mechanic, later assistant superintendent and finally general superintendent. He was advanced to assistant manager and then vice president and general manager, the position he held before his recent promotion.

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H. D. James, control expert and long a consulting engineer of the Westinghouse Electric and Manufacturing Company, has opened an engineering consulting service specializing in industrial and building problems. For manufacturers without technical staffs, the organization offers technical information, assistance in purchasing where engineering questions are involved, cost analysis, and design of equipment. Experienced engineers working under Mr. James' personal supervision are available for special assignments, including electronic and air conditioning applications.

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Frank J. Wood of Pittsburgh has accepted a position as mechanical engineer for the Brass Mill Division of Western Cartridge Company, East Alton, Ill. Mr. Wood was formerly with the Freyn Engineering Company at Leningrad, Russia, as rolling mill consultant and prior to that was with Mesta Machine Company five years as merchant mill engineer. He is an active member of the Pittsburgh District of the Association.

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The Hagan Corporation announces the appointment of E. W. Wagenseil to the newly created position of general sales manager of the Hagan Corporation and its subsidiaries—The Buromin Co., Hall Laboratories, Inc., and Calgon, Inc. The latter company has just been organized to market Calgon products.

Mr. Wagenseil was engaged in sales and engineering work in the stoker field for many years before taking charge of Air Preheater Sales for Blaw-Knox Co. in 1927. Two years ago, Mr. Wagenseil left Blaw-Knox Co. to join the sales department of Hagan Corporation, handling combustion control and boiler water conditioning.

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The Timken Roller Bearing Company and The Timken Roller Bearing Service and Sales Company, Pittsburgh district office, have moved to their new building located at 414-416 North Craig street.

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George A. Pugh, formerly vice president of the Aetna Standard Engineering Company, sailed on the Bremen April 1 for a short business trip, visiting England and the Continent.

A NEW ELECTRICAL INVENTION

Do you know the story ?

From the research laboratories comes this story of a new electrical protecting device. A fuse designed to meet the need of modern industry. A fuse with a time-lag long enough to carry many of the harmless overloads or current surges that occur on all electrical circuits.

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William F. Sailer, formerly with Alco Products, Inc., and The Griscom-Russell Company, has recently made connections with Steel and Tubes, Inc. He will be located in the Brooklyn office and will concentrate his efforts on the Oil Refinery and Marine fields.

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ASSOCIATION NOTES

COMING MEETINGS AND PAPERS

Chicago Section

K. E. Dinius, Chairman A. J. Whitcomb, Secretary
Electric Association, 20 North Wacker Drive
6:30 P. M.
April 25, 1934
X-Ray Exhibition

"Industrial Applications of X-Rays," by E. C. Page, Manager, General Electric X-Ray Corporation.

"The Nature of X-Rays and Their Practical Application," by Dr. David S. Beilin, Chicago Roentgen Society.

The nature of X-rays and their industrial application will be the subject of two papers to be presented by authorities in this field. Particular emphasis will be placed upon the industrial uses for inspecting welds, castings and similar materials for defects and flaws in construction or manufacture.

In addition, there will be an X-ray show comprising exhibits of various types of X-ray tubes, X-ray generators, fluoroscopes, X-ray robot, mobile shock-proof units and the like. X-ray films will be on display, telling the story that the X-ray has played in industrial and other fields. Visible and black light demonstrations will also be given.

The meeting will be preceded by a dinner in the Electric Association dining room on the thirty-eighth floor of the Civic Opera Building at 6:30 P. M., and the technical session will start at 7:45 P. M. in the Lighting Institute Auditorium at the same address.

Birmingham Section

E. P. Winters, Chairman J. B. Looney, Secretary
Thomas Jefferson Hotel
Dinner 6:45 P. M.
April, 1934

"Life in the U. S. R. R.," by Gordon Fox, Vice President, Freyn Engineering Company, Chicago, Ill.

"Roll Neck Bearings," by L. W. Freeman, Mica Insulator Company.

Cleveland Section

L. A. Terry, Chairman W. W. Spanagel, Secretary
Cleveland Engineering Society Rooms
May 18, 1934
Subject and speaker will be announced later.

A. I. & S. E. E.
Thirtieth Convention and Iron and Steel Exposition
September 18, 19, 20, 1934
Cleveland Public Auditorium
Cleveland, Ohio

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"The Engine Indicator, Its Design, Theory and Special Applications," by K. J. DeJuhasz, Assistant Professor of Engineering Research, Pennsylvania State College, is the title of a new book on engine indicators. It is published by Instruments Publishing Company, New York. 240 pages with approximately 300 illustrations.

Inquiries will be out in the very near future on three 42" Cold Strip Mills and two 84" Cold Strip Mills.

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Contracts have been let for the electric drives on the 54" Finishing Mill and the Blooming Mill recently purchased by Ford.

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Order will be placed shortly for a 10" and 32"x 38" Cold Strip Mill.

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AMERICAN IRON AND STEEL INSTITUTE NOTES

Continued improvement in the iron and steel industry is reflected in the February report of hours and wages just released by American Iron and Steel Institute. These figures, from 219 member companies of the iron and steel code, show the employment of 10,000 more workers during the month and a further increase in average hourly wages and in hours per week.

The total number of workers receiving hourly, piecework or tonnage wages in February was 365,305 as against 355,292 in January. The average hours per week per employee was increased from 29.2 to 31.9 in February while the average hourly wage increased from 58.3 cents to 58.7 cents.

This is the highest average hourly wage reported since the iron and steel code became effective last September. During that month, the average hourly wage was 56.7 cents and it has shown a steady increase each month since. This figure will show a considerable jump in April as a result of the 10 per cent average increase granted by the steel industry to their workers which became effective April 1.

Based on the February total of wages paid, the latest wage increase will add over $2,700,000 monthly to the steel industry payrolls. Since June, aggregate wage increases in the industry amount to approximately 36 per cent. Total wages paid in February were $27,394,221 against $26,737,393 in January.

OBITUARIES

Luther L. Knox, 63, nationally known in the steel industry, died in Pittsburgh, April 6. He was formerly vice president and director of the Blaw-Knox Steel Co., which 15 years ago was formed by a merger of the Knox Pressed & Welded Steel Co. and the Blaw Construction Co. Recently, he had been affiliated with the Pressed Steel Car Co. and was active in the design of a new-type door for open-hearth furnaces.

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Carl S. Forkum, 52, superintendent of blast furnaces, American Steel & Wire Co., Donora, Pa., died in Pittsburgh, March 19. At one time he was northern superintendent of blast furnaces, Republic Steel Corp., Youngstown, O.; superintendent of blast furnaces, Jones & Laughlin Steel Corp., Aliquippa, Pa., and of the Joseph E. Thropp furnaces at Saxton and Everett, Pa. He became associated with the American Steel & Wire Co. in 1914 as assistant superintendent of Central furnaces, Cleveland, and in 1918 was appointed superintendent of the Donora furnaces.